G. S. SCOTLAND

Memoir 92

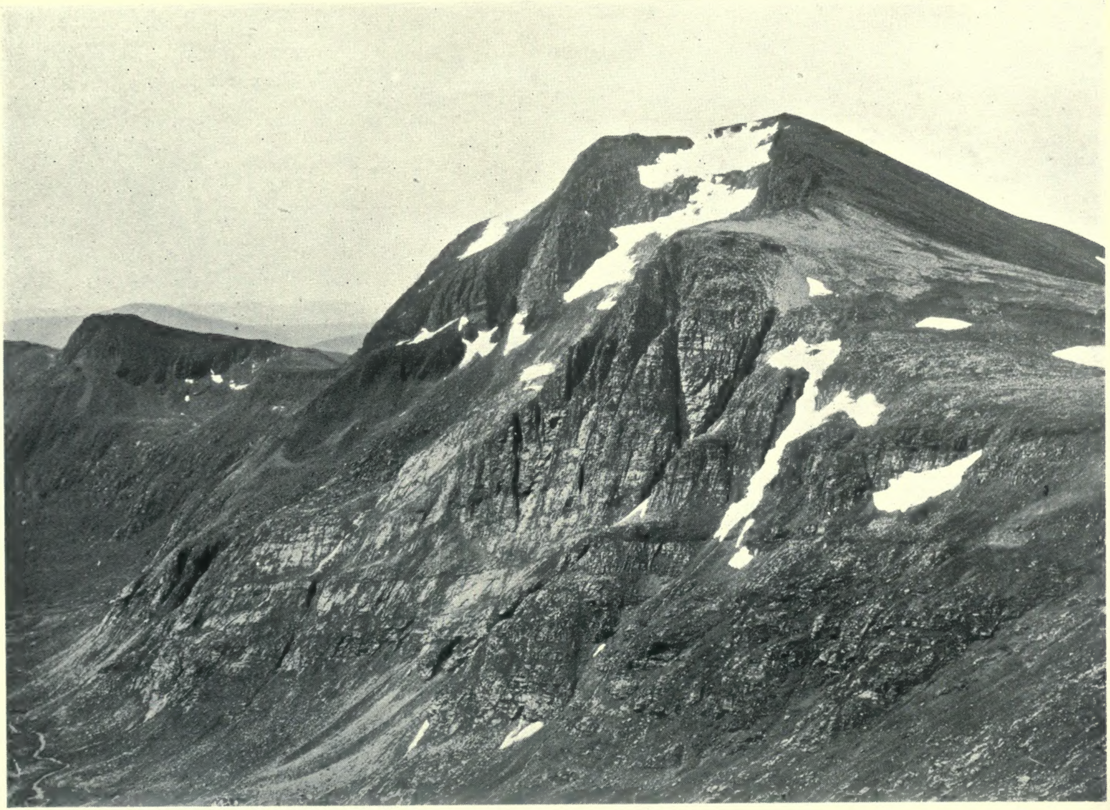
3 1761 02454322 5

Coleman Library
Department of Geological Sciences
University of Toronto

Digitized by the Internet Archive
in 2007 with funding from
Microsoft Corporation

http://www.archive.org/details/geologyoffannich00peacuoft

PLATE I. (*Frontispiece*).



ESCARPMENT, EASTERN FACE OF SGÙRR NAN CLACH GEALA, FANNICH FOREST.
Higher part of crag formed of muscovite-biotite-gneiss, lower portion of flaggy siliceous schists.

92

MEMOIRS OF THE GEOLOGICAL SURVEY,
SCOTLAND.

THE GEOLOGY
OF THE
FANNICH MOUNTAINS
AND THE
COUNTRY AROUND UPPER LOCH MAREE AND STRATH BROOM.

(EXPLANATION OF SHEET 92.)

BY

B. N. PEACH, LL.D., F.R.S.; J. HORNE, LL.D., F.R.S.;
THE LATE W. GUNN; C. T. CLOUGH, M.A., F.G.S.;
AND E. GREENLY, F.G.S.

WITH CONTRIBUTIONS BY

L. W. HINXMAN, B.A., F.R.S.E.; T. I. POCOCK, M.A.;
AND C. B. CRAMPTON, M.B., C.M.

AND

PETROLOGICAL NOTES

BY

J. J. H. TEALL, D.Sc., LL.D., F.R.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

EDINBURGH:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE
By MORRISON & GIBB LIMITED
At Tanfield.

And to be purchased from
E. STANFORD, 12, 13 & 14 Long Acre, London;
W. & A. K. JOHNSTON, LIMITED, 2 St. Andrew Square, Edinburgh,
HODGES, FIGGIS & CO., LIMITED, 104 Grafton Street, Dublin.
From any Agent for the sale of Ordnance Survey Maps.
Or through any Bookseller, from T. FISHER UNWIN, 1 Adelphi Terrace,
London, W.C., who is the sole Wholesale Agent to the Trade outside the
County of London.

1913.

Price Two Shillings and Sixpence.

LIBRARY
NOV
19
1986
UNIVERSITY
OF TORONTO

PREFACE.

THIS Memoir describes the geology of the area included in Sheet 92 of the one-inch map of Scotland. It comprises the mountainous ground bounding the upper part of Loch Maree and extending northwards to Gruinard Bay and the head of Loch Broom, the Fannich mountains in the south-east quadrant, and that part of the main watershed of the Highlands situated to the east of Strath Broom. This elevated region forms part of the county of Ross, but formerly it contained small outlying portions of the county of Cromarty.

The belt of complication due to the post-Cambrian movements crosses the sheet from Loch Broom to the alluvial plain at the head of Loch Maree. To the west of this belt lie large tracts of Lewisian Gneiss and Torridon Sandstone overlain unconformably by the Cambrian formation. To the east there is a great development of the Eastern Schists, which give rise to some of the wildest scenery in Central Ross-shire. In the north-west corner of the map there is a small patch of Triassic and Liassic strata, let down against the Torridon Sandstone by a large fault.

The Sheet was surveyed geologically by B. N. Peach, J. Horne, the late W. Gunn, C. T. Clough, L. W. Hinxman, H. M. Cadell, E. Greenly, T. I. Pocock, and C. B. Crampton. The largest part was done by the late Mr. Gunn, whose area extended from the Fionn Loch north to Gruinard Bay, thence eastwards by An Teallach, Strath Beg, and Strath Broom to Beinn Dearg, and southwards to the watershed of the Fannich mountains. Messrs. Peach and Horne took part in the mapping of the belt of complication due to the post-Cambrian movements from Strath na Sheallag to the southern margin of the Sheet. Dr. Peach also surveyed the Eastern Schists around Fionn Bheinn, and Dr. Horne the development of these rocks along the southern slope of the Fannich range. To Mr. Clough was assigned the complicated tract of Lewisian Gneiss stretching from Loch Maree to Beinn a' Chàisgein Beag; to Mr. Greenly, some isolated areas near Loch na Sheallag, the Heights of Kinlochewe, and on either side of Loch Maree; to Messrs. Hinxman, Pocock, and Crampton, parts of the Eastern Schists in the north-east and south-east corners of the map, and on Beinn nan Ramh near the head of Loch Fannich; and to Mr. Cadell, a patch of Torridon Sandstone along the north-east shore of Little Loch Broom.

Detailed descriptions of the Lewisian, Torridonian, and Cambrian rocks, and of the tectonics of the belt of complication, have already appeared in the Memoir on "The Geological Structure of the North-West Highlands," which are here reproduced in a condensed form with some of the horizontal sections. As regards the Eastern Schists the various officers have furnished descriptions of their respective areas. Perhaps the most interesting feature connected with these rocks is the account of the remarkable geological structure of the Fannich range.

Almost the whole of the petrology of the rocks within this Sheet has been done by Dr. Teall. A few specimens have been examined and reported on by Dr. Flett.

The memoir has been edited by Dr. Horne. Plates I. to V. have been prepared from photographs taken by Mr. Lunn. We are indebted to the Rev. Mr. Robertson of Rannoch for the excellent photograph of the corrie rock-basin on An Teallach, represented in Plate VI. The Bibliography given in the Appendix has been prepared by Mr. Tait.

J. J. H. TEALL,
Director.

Geological Survey Office,
28 Jermyn Street, London.
21st November 1912.

CONTENTS.

CHAPTER I.

PAGE
INTRODUCTION 1
Area 1
Physical Features 1

CHAPTER II.

FORMATIONS AND ROCK GROUPS 8
General Geological Description 8
Previous Literature 11

CHAPTER III.

THE LEWISIAN GNEISS 14
General Description 14
The Fundamental Complex 22
Ultrabasic Rocks 23
Basic Rocks 24
Acid Rocks 25
Pre-Torridonian Intrusions 26
Ultrabasic Dykes 26
Basic Dykes 27
Syenite Dyke 28
Pegmatites 28
The Loch Maree Series and some Associated Schists . . . 29
1. Mica-Schist 30
2. Mica-Actinolite-Schist 31
3. Graphite-Schist 31
4. Kyanite-Gneiss 32
5. Granular Quartz-Rock 32
6. Quartz-Schist and Quartz-Magnetite-Schist . . . 33
7. Quartz-Hornblende-Schist 33
8. Limestone 34
9. Calcareous Biotite-Hornblende-Schist 36
10. Chlorite-Schist 36
11. Hornblende-Schist and Hornblende-Chlorite-Schist . . 36
12. Hornblende-Schist with brown Mica and Pyrites . . 38

CHAPTER IV.

PAGE
THE TORRIDON SANDSTONE 39
General Description 39
Diabaig Group 41
Applecross Group 43
Aultbea Group 44

CHAPTER V.

CAMBRIAN FORMATION 46
Area from Loch Lagaidh to Strath na Sheallag . . . 46
Area from Strath na Sheallag to Kinlochewe Forest . . 48

CHAPTER VI.

POST-CAMBRIAN MOVEMENTS 51
Area from Loch Broom to Strath na Sheallag . . . 51
Area from Strath na Sheallag to Kinlochewe Forest . . 55

CHAPTER VII.

THE EASTERN SCHISTS 64
Area north of the Fannich Watershed 65
Area south of the Fannich Watershed 77

CHAPTER VIII.

GARNET-HORNBLENDE-ROCKS IN MOINE SERIES, AND DYKES OF MICA-TRAP AND LAMPROPHYRE 87

CHAPTER IX.

MESOZOIC ROCKS 89
Trias 89
Lias 90

CHAPTER X.

FAULTS 91

CHAPTER XI.

PLEISTOCENE AND RECENT DEPOSITS 95
Glaciation and Glacial Deposits 95
Ice-worn Rock Surfaces 96
Boulder Clay and Moraines 98

PAGE
Erratic Blocks 103
Fluvio-Glacial Sands and Gravels 106
Freshwater Lochs 107
Raised Beaches 109
Freshwater Alluvia 110
Peat 111
Blown Sand 111

CHAPTER XII.

ECONOMIC GEOLOGY 113
Iron-Ore 113
Limestone 114
Building Stone 115
Road Metal 115
Metalliferous Veins, &c. 115
Plantations 116
Rainfall Returns 118

APPENDIX.

BIBLIOGRAPHY—
LIST OF WORKS REFERRING TO THE GEOLOGY OF THE AREA INCLUDED IN THIS MEMOIR 120

INDEX 123

LIST OF ILLUSTRATIONS.

FIGURES IN TEXT.

PAGE
FIG. 1. Section from near Furnace, Loch Maree, to Beinn a' Chàisgein Mòr 17
,, 2. Section across Anticline near Creag Chorcurach, east of Dundonnell Lodge, Little Loch Broom . . 53
,, 3. Section from A' Mhaighdean by Mullach Coire Mhic Fhearchair to Creag Rainich 57
,, 4. Section from Slioch by Beinn a' Mhùinidh to Abhuinn Bruachaig 59
,, 5. Section from Glen Grudie by Meall a' Ghiubhais to Cromasag, south of Kinlochewe 61
,, 6. Diagrammatic Section from near the Heights of Kinlochewe by Fionn Bheinn and An Cabar to the eastern edge of Sheet 92 86
,, 7. Map showing direction of Ice-flow in Area included in Sheet 92 97
,, 8. Map of parts of Central and West Ross-shire, showing distribution of boulders of Augen Gneiss and Old Red Sandstone 104

PLATES.

PLATE I. Escarpment, eastern face of Sgùrr nan Clach Geala, Fannich Forest . . . . . *Frontispiece*
,, II. Sections across the Fannich Mountains—
(A.) Section from Beinn Bheag by A' Chailleach and Sgùrr nan Clach Geala to An Coileachan;
(B.) Section from Creag Rainich by A' Chailleach, An Sgùman, and Torran Ruadh to the Grudie River . . . . (to face) 76
,, III. Garnetiferous Muscovite-Biotite-Gneiss with lenticles of Pegmatite, Sgùrr nan Clach Geala, Fannich Forest (to face) 78
,, IV. Flaggy Siliceous Schists, east face of Sgùrr nan Clach Geala, Fannich Forest . . . (to face) 80
,, V. View of crest of east part of Fannich Mountains; plateau frost-debris in terraces (foreground to right), corries to left in north-east face of chain; Loch Fannich in middle distance . . . (to face) 98
,, VI. Loch Toll an Lochain, a corrie rock-basin in Torridon Sandstone, east side of An Teallach . (to face) 102

THE GEOLOGY OF THE FANNICH MOUNTAINS, ETC.

CHAPTER I.

INTRODUCTION.

AREA.

THE area included in this Sheet amounts to 432 square miles, of which 426 are occupied by the mainland and the remainder by sea, the latter comprising the head of Loch Broom with parts of Little Loch Broom and Gruinard Bay. The land area forms part of the county of Ross, but formerly it embraced several isolated portions of the county of Cromarty. This tract of country is defined on the east by a line drawn from the slopes of Seana Bhraigh in the north-east corner of the map, to a point near the mouth of Loch Fannich on the south. The southern boundary traverses the crest of Fionn Bheinn and runs westward to Beinn a' Chearcaill; the western margin crosses Loch Maree near Garbh Eilean and stretches northwards to Sand on the shore of Gruinard Bay; while the northern boundary extends from Gruinard Bay east by Leckmelm on Loch Broom to Meall nam Bràdhan.

PHYSICAL FEATURES.

The ground throughout this extensive tract is mountainous, and the most of it is occupied by deer forests. The only cultivated areas lie along the seacoast, also in the lower parts of Strath Beg and Strath Broom, and along the alluvial plain at the mouth of the Kinlochewe River.

A glance at the geological map will show that four dominant rock groups are represented within the area, namely, the Lewisian Gneiss, the Torridon Sandstone, the Cambrian formation and the Eastern Schists.* These furnish the key to the topography of the region and to the development of the characteristic mountain forms.

In the north-west part of the map, the ground occupied by the Lewisian Gneiss to the west of the Little Gruinard River and the Fionn Loch forms a plateau under 1000 ft., with steep, rocky hills somewhat rounded in outline, but comparatively free from glacial drift. Eastwards this plateau rises into prominent ridges or hills, as, for example, Beinn a' Chàisgein Mòr (2802 ft.), Beinn a' Chàisgein

---

* The term Eastern Schists is here used to include the "Moine Series" of the Geological Survey, and the acid and basic gneisses, resembling types of Lewisian Gneiss to the west of the post-Cambrian thrusts.

Beag (2234 ft.) and A' Mhaighdean (over 2800 ft.), whose rocky features are largely determined by the north-westerly trend of the gneiss and the basic dykes. In places the slopes are smooth, and covered with debris of local rocks. The intimate connection between mountain form and geological structure is well illustrated in the tract between the southern portion of the Fionn Loch and Loch Maree, where a great escarpment runs in an E.S.E. direction from Beinn Airidh Charr (2593 ft.) by Meall Mhèinnidh to Beinn Làir (2817 ft.). This escarpment, overlooking Gleann Tùlacha, is one of the remarkable topographical features of the region. In the sequel it will be shown that it is due to an intrusive sheet of hornblende-schist associated with the sedimentary schists of Archæan age.

The second type of scenery is characteristic of the Torridon Sandstone, whose mountain forms differ completely from those met with among the metamorphic rocks to the west and east. They present lofty escarpments with terraced outlines, due to the outcrops of beds of sandstone and grit which are traceable for miles across the plateau of Lewisian Gneiss. Under the influence of denuding agents, they give rise to huge precipitous corries with lateral ridges, and they tend to form detached masses with rounded buttresses, crossed by innumerable joints and small faults along which erosion proceeds more rapidly. Most of the distinctive outlines of Torridonian scenery are exemplified in An Teallach—perhaps the most picturesque mountain of this system in the North-west Highlands. Situated between the head of Loch Broom and Strath na Sheallag, it forms a conspicuous feature in the landscape when seen from the surrounding heights. In this mountain five peaks exceed 3000 ft. in altitude. On the eastern side three prominent ridges or spurs, all above 3000 ft., project from the central mass. The two highest points reach an elevation of 3483 ft. and 3474 ft. respectively (see Plate VI.).

South from Loch na Sheallag this scenic type is continued in Beinn Dearg Mhòr (2974 ft.) and Beinn Dearg Bheag, and along the great western escarpment of Beinn a' Chlaidheimh and Sgùrr Bàn to Beinn Tarsuinn. Beyond Lochan Fada we encounter the buttresses and dip slopes of Slioch (3217 ft.), where this pile of sediments rests on a highly uneven floor of Lewisian Gneiss. South from Loch Maree, between the Grudie River and the western margin of the Sheet, these mountain forms reappear, culminating in Beinn an Eòin (2801 ft.) and Beinn a' Chearcaill (2376 ft.) in the south-west corner of the map.

The third type, though of limited development, is, nevertheless, distinctive. It is due to the presence of the Cambrian quartzites, which give rise to a prominent escarpment resting on the Torridon Sandstone. Sometimes they form long, glaciated dip slopes, as, for instance, on Sgùrr Bàn, north from Lochan Fada; sometimes they are thrown into a complicated system of folds, as in the tract south from the head of Loch Maree.

The fourth type of scenery is presented by the Eastern Schists, which occupy the eastern half of the region under description. This area forms part of the Highland plateau, running along the main watershed of the country, which has been deeply trenched by river systems developed since Eocene time. It is observable that these crystalline schists give rise to less rocky contours than the Lewisian

Gneiss to the west. In the lower portion of the plateau numerous ribs of schist project through peat and glacial deposits. But in the mountainous region rising above the limits of the drift the hilltops and slopes have frequently a thin veneer of grass, turf, peat or loose debris of local rocks. In this region also there are lofty escarpments and precipitous corries illustrating the features characteristic of the flaggy siliceous schists and the massive muscovite-biotite-gneiss of the Moine Series (see Plate I., Frontispiece).

In the north-east corner of the area, occupied by the Eastern Schists, there is a belt of high ground stretching from Beinn Dearg (3547 ft.) to Seana Bhraigh with five peaks exceeding 3000 ft. in altitude. The most prominent mass of elevated ground, however, is the Fannich group of mountains to the north of Loch Fannich, extending for a distance of seven miles in an E.S.E. and W.N.W. direction, and containing eleven peaks over 3000 ft. in height. In the sequel it will be shown that some of the prominent topographical features of this mountain group are due to the remarkable geological structure of the chain.

In this connection reference ought to be made to the exposure by denudation of topography belonging to ancient geological periods. Thus along the tract bordering the western limits of the Torridon Sandstone the present outlines of the Lewisian Gneiss are, to a considerable extent, a renewal of the pre-Torridonian land surface which can be shown to have been one of high relief. The most conspicuous instance is that afforded by the slopes of Slioch, where the nearly horizontal beds of Torridon Sandstone are seen to envelop three prominent hills of Lewisian Gneiss—one over 2000 ft. in height — with intervening valleys. Another eminence of pre-Torridonian age rises to a great altitude between Beinn Dearg Mhòr and Beinn Dearg Bheag, south from Loch na Sheallag, which are mainly composed of Torridon Sandstone and are linked with each other by a narrow bridge of that material. South from Loch Maree the tops of at least three gneiss hills are seen to protrude through the Torridonian strata in the Srath Lungard district in the south-west part of the map. Again, the disposition of the Torridonian sediments on the south-west side of Lochan Fada shows that the deep valley of Gleann Tùlacha and of Lochan Fada, together with the great escarpment that bounds the Beinn Làir chain to the south, must have been developed in pre-Torridonian time and have been laid bare by the removal of the overlying strata.

W. G., B. N. P., J. H.

Furthermore, it is highly probable that the low plateau of Lewisian Gneiss along the western limits of the area may be in part a restoration of the pre-Triassic land surface. This plateau, whose general level is over 600 ft., rises eastwards, as already indicated, up to lofty ridges from 2000 to 3000 ft. in height. But to the west and north it extends into the areas included in Sheets 91, 100 and 101, where outliers of Triassic and Jurassic strata are distributed over it in such a manner as to suggest that the plateau is in great part a renewal of that upon which the Mesozoic strata were laid down. If the strata composing the faulted inlier of Triassic and Liassic rocks in the north-west corner of the map were restored to their original level (the amount of downthrow being about 1000 ft.), they would be thick enough not only to cover the lower plain but also to abut against the slopes of the higher plateau.

The main watershed of the country, between the streams that flow eastwards into the North Sea and westwards into the Atlantic, traverses the region under description in a highly sinuous manner (Fig. 7, p. 97). In the high ground in the north-east part of the map it runs from north to south near the eastern limits of the Sheet, but to the south of Loch Droma it bends westwards for a distance of eleven miles along the crests of the Fannich mountains, thence curving eastwards to beyond Fionn Bheinn (3060 ft.). This great westward deflection of the watershed round the head of Loch Fannich basin has obviously a direct relation with the evolution of the river systems, as will now be shown.

In consequence of the position of the main watershed, as regards this Sheet, the streams flowing eastward, with the exception of those in the Fannich area, are not important. Those in the extreme north-east corner, north from Seana Bhraigh, are tributaries of the River Oykell, and those to the south of that mountain are sources of the River Carron, both of which rivers enter the head of the Dornoch Firth. The streams on either side of Beinn Dearg and the Abhuinn a' Ghiubhais Lì, south of Loch Droma, help to form the Black Water—an affluent of the River Conan. Another tributary of the Conan issues from Loch Fannich.

To the west of the main watershed the River Douchary is the principal branch of the Rhidorroch River, which enters the sea at Ullapool on Loch Broom. The Broom River is formed by the junction of the two streams that rise near Sgùrr Mòr and the head of Loch a' Bhraoin respectively. The Dundonnell River, which enters little Loch Broom, finds its source near Creag Rainich. The Gruinard River, issuing from Loch na Sheallag and discharging into Gruinard Bay, is formed by two streams, Abhuinn Srath na Sealga and Abhuinn Gleann na Muice, which unite just above the head of the loch. The Little Gruinard River, which also flows into Gruinard Bay, has its sources near the head of the Fionn Loch. The Abhuinn Bruachaig—a tributary of the Kinlochewe River—drains a wide district by means of three affluents, the first rising in the valley of Gleann Tùlacha, the second on the southern slopes of Mullach Coire Mhic Fhearchair, and the third on the north-east declivity of Fionn Bheinn, south from the head of Loch Fannich. These are some of the more important lines of drainage in the region described.

In connection with the trend of these river systems, it is observable that the behaviour of the main watershed in this region is in accordance with the evidence presented by the Highland plateau north of the Caledonian Canal. Throughout this extensive tract we find that, in the through valleys, the watershed of the tributaries of the rivers flowing east lies to the west of that of the main rivers themselves. The phenomena point to the conclusion, that the headwaters of the main streams flowing east have been captured by the westward-flowing rivers, and that the latter have become obsequent in valleys previously carved out by an eastward drainage system. Hence it arises that the high plateau is traversed from west to east by comparatively low passes at the watershed.

For example, the River Douchary, which was evidently at one time a tributary of the Oykell through the hollow now partly occupied by Loch an Daimh (Sheet 101), has been captured by the Rhidorroch River, the resulting pass being only 820 ft. above sea-level. A more conspicuous instance is furnished by the River Broom, which first stole the waters of the Abhuinn Cuileig and afterwards cut backwards into the valley excavated by the Glascarnoch River (Sheet 93)—an affluent of the Black Water branch of the Conan. In the course of this recession the Broom tapped in turn some of the burns draining the northern slopes of the Fannich range and some to the north-west of Loch Droma, till the watershed now coincides with a pass (915 ft.) to the east of that loch. In the sequel it will be shown that these passes have been covered by ice moving westward during the maximum glaciation, and that lochs have been left at or near the actual watershed.

The evidence relating to minor cases of capture is perhaps more apparent. Thus the burns flowing eastwards from Sgùrr Bàn and Mullach Coire Mhic Fhearchair evidently formed at one time the headwaters of the stream that now flows into Loch a' Bhraoin. These have been deflected and led away by the Amhainn Loch an Nid through Loch na Sheallag into Gruinard Bay. In like manner the rivulet draining the southern declivity of Mullach Coire Mhic Fhearchair runs south-eastwards for about three miles in the direction of Abhuinn a' Chadh' Bhuidhe—a tributary of Loch Fannich. But the waters of this rivulet have been stolen by the burn flowing through Gleann Tanagaidh—an affluent of Abhuinn Bruachaig, which drains into the Kinlochewe River.

Again, it is highly probable that the valley in which Lochan Fada now lies was once occupied by a stream that drained into Gleann na Muice, and thence by the Srath Chrombuill River, the Fannich depression and the Grudie River into the Conan. This system has been tapped by two separate streams flowing into Loch Maree. Thus the waters of the Gleann na Muice and Srath Chrombuill portion have been captured by the Abhuinn Bruachaig at the Heights of Kinlochewe, while Lochan Fada has been drained by Abhuinn an Fhasaigh and led directly into Loch Maree, there being a fall of about 1000 ft. in the course of the latter stream within a distance of three miles.

The examples above adduced of the modification of former drainage systems point to the conclusion that the steep gradient of the westward-flowing streams has been an important factor in the deflection and capture of the headwaters of the rivers flowing towards the east. B. N. P., J. H.

Many of the smaller streams, especially in the district of the Eastern Schists, run in deep and narrow gorges diversified by waterfalls, and a few of the larger streams also have formed cañons, as, for instance, the Dundonnell River above Dundonnell, and the two branches of the River Broom south of Braemore. The beautiful ravine on the eastern branch of the latter is a typical example of this kind of scenery produced by river action in the flaggy schists of the Moine Series. In several instances these ravines run along lines of fault or joint planes.

It is worthy of note that the best-developed gorges are situated mainly on the rise between the inland portions of the continental shelf and the intermediate plateau, varying in height from 1000 to 1500 ft. above sea-level. The deepest cañons occur in the main valleys crossing this slope, especially where the rise coincides with the outcrop of the siliceous schists of the Moine Series. The gorges in such situations were probably initiated and largely developed during the retreat of the confluent glaciers, when the cutting power of the streams was intensified by the escape of water from the melting ice front. During this stage of the glacial period the main valleys draining westwards received more ice than the normal outflow from their respective catchment basins.

The great displacements that traverse this Sheet have in some cases given rise to conspicuous surface features. The straight north-east side of Loch Maree coincides with a line of fault or shatter belt, and the trend of the Loch Broom valley is attributed to the same cause. The course of the Little Gruinard River and of the lower part of the Inverianvie stream are additional examples. The outcrop of the Moine thrust, the most easterly of the post-Cambrian displacements, which crosses the Sheet from north to south, gives rise, in some places, to a well-marked hollow. It is mainly due to the soft Cambrian strata (Fucoid Beds) that overlie the strongly resisting quartzites at their base and are overlain in turn by thrust materials. A dip slope of quartzite is established on the west, and an escarpment of displaced masses capped by Moine schists on the east. This escarpment is best seen on the east side of Amhainn Loch an Nid in the Dundonnell Forest. The level of the stream just below its exit from Loch an Nid is about 900 ft., from which the ground rises steeply up to the top of Creag Rainich (2646 ft.), about a mile to the east.

There are several large freshwater lochs in the region under description, and a great number of small size. The largest is Loch Maree, thirteen miles in length, with richly wooded islands. The western portion of the lake is beyond the limits of this map. The next in size is Loch Fannich, seven miles long, which is closely followed by the Fionn Loch and the Dubh Loch, these two forming practically one sheet of water. Lochan Fada, north from Slioch, and Loch na Sheallag are each three and a half miles in length, and Loch a' Bhraoin two and a half miles. Small lochs are numerous on the rocky plateau of Lewisian Gneiss west of the Fionn Loch, and on either side of the Little Gruinard River, between 400 ft. and 800 ft. above the sea. They are also very abundant on the plateau of the Eastern Schists between the Loch Broom and Strath Beg valleys, where the ground is between 1000 ft. and 1500 ft. in altitude. Many of the lochs lie in rock-basins, some are ponded by moraines, and a large number rest in drift and peat.

In the sequel it will be shown that the topography of the whole region has been largely modified during the Glacial period. In addition to the general erosion of the solid rocks there is evidence pointing to the conclusion that, by ice action, cols have been lowered, valleys have been deepened and made U-shaped, rock-basins have been excavated, and corries developed out of shallow depressions at the heads of streams. The confluent and valley glaciers have left their spoor in the form of numerous lateral and terminal moraines.

The population is small, and consists mainly of crofters who cultivate land mostly adjoining the sea. The principal arable land embraces a stretch of three miles in the lower part of Strath Beg, and another area, four and a half miles long, in the Loch Broom valley. The areas now under sheep are comparatively small; the chief being the ground west of the Little Gruinard River, a strip along the south side of Little Loch Broom, all the ground between Great and Little Loch Broom, southward to Allt a' Chàirn, and a limited tract E.N.E. of Kinlochewe. The remainder of the region is occupied by deer forests. W. G., B. N. P., J. H.

CHAPTER II.

FORMATIONS AND ROCK GROUPS.

THE geological formations occurring within the region under description are presented in the subjoined table. These are arranged in stratigraphical succession, except in the case of the metamorphic rocks, where the order given in the table does not necessarily imply sequence in time.

Recent and Pleistocene.		Blown sand.	
		Peat.	
		Freshwater alluvium—river gravels.	
		Marine alluvium—raised beaches.	
		Glacial sand and gravel.	
		Morainic drift with some boulder-clay.	
Lias.		Limestone.	
Trias.		White and mottled sandstone with red clay and conglomerate.	
Cambrian.		Limestone.	
		Serpulite Grit	*Olenellus* Zone.
		Fucoid Beds	
		Pipe Rock.	
		Basal or False-bedded Quartzite.	
Torridonian.		Aultbea Group.	
		Applecross Group.	
		Diabaig Group.	
Metamorphic Rocks.	Moine Series.	Psammitic and pelitic schists and gneisses, and undifferentiated schists.	
	Lewisian Gneiss.	Massive and foliated, pyroxenic, hornblendic and micaceous rocks.	
		Serpentine and peridotite.	
		Quartz-schist, mica-schist, graphite-schist and limestone (Loch Maree Series).	
Intrusive Igneous Rocks.		Lamprophyre.	
		Syenite.	
		Muscovite-pegmatite.	
	In Moine Series.	Hornblende-schist.	
	In Lewisian Gneiss.	Hornblende-schist.	
		Hornblendite.	
		Serpentine and peridotite.	

GENERAL GEOLOGICAL DESCRIPTION.

In Chapter I. brief reference has been made in connection with the topography to the distribution of the four important rock groups which enter into the geological structure of the district.

The Lewisian Gneiss, which occupies a large part of the area included in the western half of the map, comprises (1) massive and foliated, ultrabasic, basic and acid rocks that have affinities with plutonic igneous products and have been termed the Fundamental Complex; (2) quartz-schist, mica-schist, graphite-schist and limestone, evidently representing an altered sedimentary series; (3) basic and ultrabasic dykes and sills intrusive in the massive gneisses and altered sediments. While the members of the Fundamental Complex are for the most part of igneous origin (orthogneisses), it is not improbable that some of them may be of sedimentary origin (paragneisses). The general strike of the foliation of the massive gneisses and the trend of the dykes is towards the north-west. But in places both the massive gneisses and the dykes have been subjected to shearing processes whereby a new foliation has been developed. The relations of the altered sediments north of Loch Maree to the members of the Fundamental Complex have not been definitely determined. It is clear, however, that the massive gneisses, the altered sediments, and the intrusive dykes and sills have been affected by a common system of folding in pre-Torridonian time.

The Torridon Sandstone rests unconformably on a highly eroded land surface of Lewisian Gneiss. The three divisions of the system are here represented, but the members of the middle or Applecross division have by far the largest development. At the base there is usually a conglomerate containing fragments of Lewisian rocks which is overlain by comparatively fine sandstones, mudstones and dark grey or black shales. The central division is composed of coarse red arkoses with scattered pebbles, which attain a thickness of several thousand feet. The higher part of the formation, which, however, seldom appears, consists of brown sandstones, mudstones and shales.

Next in order come the Cambrian strata, which rest unconformably on the Torridon Sandstone. The whole sequence of this formation, as developed elsewhere in the North-West Highlands, does not occur in the region under description. The quartzites from 500 ft. to 600 ft. thick, the Fucoid Beds and Serpulite Grit, are displayed with their characteristic features in the undisturbed area to the west of the post-Cambrian displacements. In some places the basal limestone is seen to rest normally on the Serpulite Grit, but, in general, the natural sequence of the strata is interrupted at the horizon of the Fucoid Beds within the limits of this Sheet. It is worthy of note that the section showing the typical development of trilobite-bearing bands in the Fucoid Beds occurs on the northern slope of Meall a' Ghiubhais, south from Loch Maree.

The belt of complication due to the post-Cambrian movements crosses the area from the shore of Loch Broom to the southern margin of the map beyond the head of Loch Maree. Two displacements of special importance are represented, the more westerly being the Kinlochewe thrust, which is regarded as the southern prolongation of the Ben More line of disruption, and the Moine thrust. The former brings forward in certain parts a slice of Lewisian Gneiss with the Torridon Sandstone and Cambrian Quartzites, and the latter, a series of metamorphic rocks grouped under the general term of the Eastern Schists. In the northern part of the region the belt of complication is narrow. The outcrops of the two great thrusts approach each other closely; indeed, between Strath Beg and Strath na Sheallag the Eastern Schists overlap all underlying thrust materials and rest directly on undisturbed Cambrian strata. South from Loch an Nid the belt widens, till at the Heights of Kinlochewe it is three miles broad. On the rocky plateau north from the Kinlochewe River the structure is extremely complicated. The plane of the Kinlochewe thrust has been folded, and the displaced materials overlying it have been so denuded as to expose the imbricate structure of the Fucoid Beds, Serpulite Grit and limestone beneath. Reference ought to be made here to one of the remarkable tectonic features of the region, namely, the outlier of Lewisian Gneiss and Torridon Sandstone on Meall a' Ghiubhais which has been isolated by denudation from the main mass of thrust materials overlying the Kinlochewe thrust-plane (Fig. 5, p. 61). The planes of disruption, except where they are folded, are inclined to the E.S.E., like the strata above and below them.

As already indicated, the Eastern Schists occupy the eastern half of the area included in the map. They comprise (1) mylonised rocks; (2) granulitic quartzose schist and muscovite-biotite-gneiss or schist representing the psammitic and pelitic types of the Moine Series; and (3) a limited development of micaceous and hornblendic rocks, resembling, in some particulars, Lewisian types to the west.

Near the Moine thrust-plane, and generally in the large area that embraces Strath Beg and Loch Broom, the dip is fairly regular, at low angles of from 10° to 20°, and in some cases 30°. The direction is mostly towards the south-east, and there are few signs of any plication, only some occasional undulations and contortions. Along certain lines, however, the schists have been much ridged up and contorted. One of these runs in an E.N.E. direction, crossing Loch Broom between Ardcharnich and Leckmelm, and, though a comparatively narrow band, may be traced for several miles. In the eastern portion of the Sheet, beyond the thirteenth milestone * from Ullapool, the structure is complicated. The strata strike generally north and south at high angles, and there is much overfolding and puckering, the high eastern dip being an inverted one in relation to the gentle dip of the same rocks about Braemore.

From the point of view of tectonics, the most interesting part of the area of the Eastern Schists is that embracing the Fannich mountains and the tract immediately to the north of it. In that region, several bands of rock with more or less distinctive lithological characters have been mapped out. One of these bands contains micaceous and hornblendic rocks, some of which resemble Lewisian types to the west. When traced in the field these bands behave as if they were synclinally arranged, but if the correlation of one of the groups with Lewisian types to the west be correct, it would follow that the rocks form a great recumbent fold with an amplitude of several miles.

The Triassic and Liassic rocks occupy a very small area in the north-west corner of the map. The former consist of white and red sandstones, interstratified near the top with green and mottled shales or marls, and as yet have not yielded organic remains. The latter, so far as observed, are composed of thin-bedded argillaceous limestones with fossils.

---

* This milestone is about a mile and a quarter above Braemore Lodge.

PREVIOUS LITERATURE.

In the memoir on "The Geological Structure of the North-west Highlands of Scotland" (1907), a detailed account is given of the literature bearing on the controversy between Sir Roderick Murchison and Professor Nicol regarding the succession of the rocks in that region. It is desirable to recall certain points in that historical sketch on account of their bearing on the ground now being described. It was there shown that Nicol's main conclusions had been confirmed by the work of the Geological Survey, namely: (1) that the quartzite-limestone series (Cambrian) rests unconformably on the Torridon Sandstone; (2) that the limestone is the highest member of the quartzite-limestone series; (3) that the so-called Upper Quartzite and Upper Limestone of Murchison's sections are merely the repetition of the lower quartzite and limestone due to folds or faults; (4) that there is no conformable sequence from the quartzites and limestones into the overlying schists; (5) that the line of junction is a line of fault, indicated by proofs of fracture and contortion of the strata.

In this connection reference ought again to be made to the important observations by Professor Bonney on the sections in Abhuinn Bruachaig near the Heights of Kinlochewe, within the limits of the map. He pointed out that, with the exception of some dykes, the so-called "intrusive syenite" of Glen Logan (Glen Bruachaig) is merely a granitoid variety of the Hebridean Gneiss. He showed that its junction with the quartzites, Fucoid Beds and limestone is a faulted one, and indicated the direction of the fault. In opposition to Dr. Hicks he contended that the newer series (Eastern Schists) in Glen Bruachaig belongs to the metamorphic rocks, as they consist of dark green schists, dull-coloured mica-schists and micaceous quartzites.*

With reference to the work of Dr. Hicks in this region, it may be sufficient to state that he regarded the schists of Ben Fyn (Fionn Bheinn in Sheet 92) as forming a group in the metamorphic series. He classified the pre-Cambrian rocks in three divisions: (1) lower, consisting of massive gneisses (Loch Maree); (2) middle, comprising more banded gneisses (Loch Shiel); (3) upper, composed of crystalline schists (Ben Fyn).†

The occurrence of small patches of red sandstone on the shores of Loch Gruinard was recorded by MacCulloch, who considered it to be the equivalent of the "Red Marl" of English geologists.‡ Subsequently this deposit was referred to by Sedgwick and Murchison, who indicated its resemblance to the New Red Sandstone of England, and also to some beds seen below the Lias in Skye.§

In his paper on the Newer Red Sandstone near Loch Gruinard, Professor Nicol notes an interesting point, namely, that the conglomerate belonging to this series contains fragments of quartzite and limestone, which he identified with the quartzite and limestone of the neighbouring mountains* (Cambrian). He discovered Lias boulders on the shore near Tinafuline† opposite Isle Ewe, and Professor Judd collected Lower Lias fossils from boulders at the same place.‡ Both regarded these blocks as derived from rocks *in situ* not far off, but they were not aware that the Lower Lias occurs in place at three or four localities farther to the north in the neighbourhood of Sand and close to Gruinard Bay.

---

* *Quart. Jour. Geol. Soc.*, vol. xxxvi. (1880), p. 93.

† *Quart. Jour. Geol. Soc.*, vol. xxxix. (1883), p. 141.

‡ "Description of the Western Isles of Scotland" (1819), vol. ii. pp. 65 and 99, and vol. iii. p. 54.

§ "On the Structure and Relations of the Deposits contained between the Primary Rocks and the Oolitic Series in the North of Scotland," *Trans. Geol. Soc.* (Second Series), vol. iii. (1835), p. 156.

In 1880, Sir A. Geikie suggested that the hummocky contours of the Lewisian Gneiss, especially in the neighbourhood of Gairloch, bear a striking resemblance to the surface which geologists now always associate with the action of glacier ice. He contended that these rocks would never have assumed such a contour if exposed merely to ordinary subaerial disintegration. He also compared the basal Torridonian breccia of that district to moraine-stuff.§

In 1896, Mr. J. G. Goodchild advanced the opinion that the desert conditions now obtaining in the Sinaitic peninsula are the exact counterpart of those that prevailed in pre-Cambrian time in Sutherland and Ross. In his opinion, the felspars in the Lewisian Gneiss, instead of being slowly kaolinised by the action of rain-water charged with carbonic acid, gave way under the strain set up by extreme expansion and contraction, due to rapid changes of temperature. The ferro-magnesian minerals of the gneissoid rocks, having different coefficients of expansion from those of the other constituents, splintered into fragments so small that they were easily blown away as dust by the wind. Possibly in the case of the Torridonian strata these materials from the old gneissic mountains may now and then have been distributed by the agency of lakes, but the action of water may have been there limited to the distribution of the disintegrated materials by the transient torrents after the heavy rains which occasionally deluge such regions.‖

In 1897, Professor Penck gave an account of his visit to the North-West Highlands, during which he examined typical sections in Assynt and in the Loch Maree district.¶ Regarding the hummocky structure of the Lewisian Gneiss and the overlying Torridon breccias, he inferred that they did not imply submarine, lacustrine or glacial conditions. In his opinion the phenomena could only be accounted for by supposing the existence of a dry continental climate, the main erosive agents being large changes of temperature, wind and occasional torrential rains.

Subsequently, from an examination of the felspars collected from the Torridon Sandstone at Kinlochewe, Dr. Mackie concluded that a glacial or subglacial climate prevailed during Torridonian time.**

---

* *Quart. Jour. Geol. Soc.*, vol. xiv. (1858), p. 168.

† *Op. cit.* p. 169.

‡ *Op. cit.* vol. xxxiv. (1878), p. 660.

§ *Nature*, vol. xxii. (1880), p. 400; also in "Geological Sketches at Home and Abroad," 1882, p. 167.

‖ "Desert Conditions in Britain," *Trans. Edin. Geol. Soc.*, vol. vii. (1893–98), p. 221.

¶ "Geomorphologische Probleme aus Nord-west Schottland," *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, Band xxxii. (1897), No. 3, pp. 146–191.

** "The Felspars Present in Sedimentary Rocks as Indicators of the Conditions of Contemporaneous Climate," *Trans. Edin. Geol. Soc.*, vol. vii. (1893–98), p. 443.

In the course of the Bathymetrical Survey of the freshwater lochs of Scotland carried out under the direction of Sir John Murray and Mr. Laurence Pullar, several of the lakes included in this Sheet were sounded. In the sequel (Chapter XI.) special reference will be made to the results obtained.* W. G., J. H.

* "Bathymetrical Survey of the Scottish Freshwater Lochs, under the direction of Sir John Murray and Laurence Pullar, during the years 1879-1909," vols. i.-vi. (1910).

CHAPTER III.

THE LEWISIAN GNEISS.*

General Description.

The Lewisian Gneiss, as already indicated, forms about half of the area lying to the west of the Moine thrust. The largest tract extends from the sea near the north-west corner of the map southwards to Loch Maree, where it is truncated by a great fault striking north-west along the loch. If we place the one-inch maps 91 and 92 together in proper position it may seem as if the Lewisian rocks on the south-west side of the Loch Maree fault have been shifted laterally towards the north-west for a distance of about nine miles. As, however, the pre-Torridonian land surface was extremely uneven on both sides of Loch Maree, and consisted of steep mountain slopes with an intervening hollow in which ran a line of fault, it is quite possible that the straight cliffs in which the Lewisian rocks now end on the north-east side of the loch are of pre-Torridonian age, though they have also been affected by fault-movements of post-Torridonian time.†

Various detached masses of Lewisian Gneiss occur along the central region between Kinlochewe and Loch Broom, one of which is an inlier, north from the head of Loch Maree, partly bounded on the east by the Fasagh fault.‡ The others have been carried westward by post-Cambrian thrusts. The largest of these displaced masses, extending from Loch an Nid to the Kinlochewe River, is more than eight miles in length, and is of considerable interest in the history of geological research, as it includes the so-called syenite of Glen Laggan,§ which was recognised by Professor Bonney in 1879 as a faulted mass of Hebridean (Lewisian) gneiss.||

On the south-west side of the Loch Maree fault the gneiss west of the post-Cambrian dislocations forms three small inliers within the Torridon Sandstone area, and also the eastern extremity of the large tract which extends from Loch Maree through one-inch map 91 to the sea at Gairloch. Several small thrust stripes occur on the sides of Meall a' Ghiubhais, the hill two miles west of the head of Loch Maree.

---

* For further particulars, reference may be made to "The Geological Structure of the North-West Highlands," *Mem. Geol. Surv.*, 1907, particularly to parts of chapters iv., v., vi., xi., and xii.

† The post-Torridon fault is described in Chapter X.

‡ This dislocation is described in Chapter X. The cottage from which this fault takes its name is not marked in the new edition of Sheet 92. It stood on the shore of Loch Maree, near the mouth of Abhuinn an Fhasaigh.

§ "Glen Logan" of Prof. Heddle, the glen in which Abhuinn Bruachaig flows.

|| "Petrological Notes on the Vicinity of the Upper Part of Loch Maree," *Quart. Jour. Geol. Soc.*, vol. xxxvi. (1879), p. 93.

In many localities, perhaps particularly on the sides of Fionn Loch and the slopes of Beinn a' Chàisgein Mòr, the rock is thickly covered with drift, but where the solid gneiss is exposed it offers a striking contrast to the adjacent Torridonian rocks. Its face is stamped with the signs of much greater age, of many different movements and episodes of intrusion which were all completed before the Torridonian formation began to accumulate.

The earlier bands of gneiss, and also many later pre-Torridonian dykes, strike in most places nearly north-west, or in some direction between north-west and west, and they are steeply inclined, while the Torridonian rocks have commonly a gentle easterly dip or are rolling about at low angles. A band of hornblende-schist forms the summits of Beinn Làir and Beinn Airidh Charr, making at its north-eastern margin a long range of magnificent crags stretching for about six miles in a north-westerly direction. Near the south-eastern end the cliffs diminish in height, become partially hidden under Torridonian outliers, and are finally completely covered by the mountain masses of Slioch.

The inlier of hornblende-schist in Srath Lungard, close to the south-western margin of the map, is greatly obscured by morainic drift, and possibly extends over a much larger area than that represented. The area west of the Lochmaree Hotel is one of the most accessible, and is also almost free from drift.

As in the North-West Highlands generally, the chief rocks composing the gneiss are divisible into two series, namely:—

1. An intricately arranged mass of ultrabasic, basic and acid rocks, partly massive and partly foliated, which has been called the Fundamental Complex.
2. A series of later intrusive dykes, chiefly basic and ultrabasic, which are often foliated, and which usually strike between west and north-west.

In addition to the above two groups, the district to be now described contains also another, namely:—

3. A series of beds including limestone, mica-schist, graphite-schist and quartz-schist, which are believed to be of sedimentary origin. They may be termed the Loch Maree Series, as they are well seen on the north-east side of this loch.

Series 3 is of special interest, as, if it is really of sedimentary origin, it is probably as old as any known sedimentary series either in Scotland or any other part of western Europe. It was the belief of the older observers that the Lewisian Gneiss, like the primitive gneiss everywhere, was on the whole of sedimentary origin. In later years, after the igneous character of many of these rocks had been recognised, Dr. Hicks was the first to maintain that some of the schists near Loch Maree and Gairloch, in the adjoining one-inch map 91, were metamorphosed sediments.* The work of the Geological Survey has helped to confirm this view, and has also disclosed, in the northern part of the map, another zone of highly sheared rocks striking from Beinn Dearg Bheag in a north-westerly direction to Loch na h-Uidhe, which may also possibly be of sedimentary origin.

---

* "The Pre-Cambrian Rocks of West and Central Ross-shire," *Geol. Mag.*, p. 104, 1880.

The original relations of the Loch Maree beds to the more massive gneisses, for the most part orthogneisses or gneisses of igneous origin, are by no means clear. The former are only found in specially sheared belts, and their boundaries with the massive gneisses are in most cases, if not all, lines of pre-Torridon thrust or fault.

Some observers, including the late Mr. Gunn, have favoured the view that the Loch Maree beds belong to a higher and newer series than the massive gneisses, upon which they probably lay at one time unconformably, the absence of any clear unconformity being due to the amount of metamorphism and shearing which the two series have experienced in common.

Others, including Mr. Clough, are more impressed by the fact that some of the supposed sediments—for instance, the kyanite-gneisses near Carnmore, rather more than four miles north-east of the cluster of islands in Loch Maree, and the limestone rather more than a mile and a quarter north-east of the outlet of Loch Bad an Sgalaig, one-inch map 91—lie within massive gneisses of common type and seem to pass gradually into them. It is suggested, therefore, that many of these massive gneisses may be paragneisses,—gneisses of sedimentary origin,—there being much more sedimentary material in the Lewisian Gneiss than our present knowledge enables us to differentiate. There is no evidence of the intrusion of any of the massive gneisses into the supposed sediments, but this may possibly be accounted for by the great pressure under which the supposed intrusions took place.

The broadest band of the Loch Maree beds stretches from Letterewe to the foot of Abhuinn an Fhasaigh, and may be called the Furnace band. Its length from south-east to north-west is about five miles, and its greatest breadth, including various bands of hornblende-schist, nearly three-quarters of a mile. Another, the Gleann Tùlacha band, can be traced from Lochan Fada along Gleann Tùlacha to the foot of Srathan Buidhe, and thence round the north and west sides of Beinn Airidh Charr.

Between the Furnace and Glen Tùlacha belts several others of less breadth can be followed north-west from the west side of Loch Garbhaig. One—the Beinn Airidh Charr band—is visible on the south-east side of that mountain, and a second—the Folais band—in a north-and-south burn from two-thirds of a mile north to 150 yds. west of Folais.* Both these bands are folded by a common system of folds with axial planes striking north-west. The Folais band contains the Letterewe limestone, formerly quarried near Folais, which is traceable for several miles. A considerable fault runs in a S.S.W. direction from the foot of Loch Garbhaig to Loch Maree, and on its south-east side a band of mica-schist occurs near the limestone and can be traced south-east until it coalesces with the mica-schist of the Furnace band.

The tectonic relations of the different bands described are obscure. The Gleann Tùlacha, Beinn Airidh Charr and Folais bands are certainly all folded into a complex syncline striking north-west—which may be called the Letterewe syncline—the north-east limbs of which generally dip south-west, while the south-west limbs are themselves plicated, sometimes dipping north-east and at other times south-west. The hornblende-schist between the Furnace and the Folais bands is separated from the hornblende-schist that overlies the Gleann Tùlacha band by the Beinn Airidh Charr sediments. Hence these bands of hornblende-schist cannot be the same, nor can the Furnace band be the same as that of Gleann Tùlacha unless the rocks were already folded before the development of the Letterewe syncline, which, however, is not an improbable supposition.

---

* Not named on the one-inch map. About a quarter of a mile north from Letterewe.

An attempt is made in Fig. 1, p. 17,* to show the supposed tectonic relations of the most important rocks between Loch Maree and Beinn a' Chàisgein Mòr. The section is drawn across the Letterewe syncline, almost at right angles to the axis, and does not show the evidence that favours the existence of an earlier fold. The centre of the syncline is chiefly occupied by massive pinkish gneiss intersected by many bands of hornblende-schist, some of which are certainly foliated basic dykes. The gneiss is always separated from the Folais and other sediments by a folded zone of mylonised rocks, and in its present position usually overlies these sediments over an area four miles long by three-quarters of a mile broad. This, however, is not always so, for in some places the south-west limb of the syncline is vertical or inclined towards the south-west. It is not certain that this superposition of the gneiss was originally brought about by thrusting, for the present synclinal arrangement of the rock masses is later than most of the mylonising. It cannot be determined how the mylonites were inclined before the syncline was formed. Perhaps they were nearly vertical. Nor can the amount of movement be estimated which has taken place along the mylonites that now underlie the pink gneiss, seeing that, before the

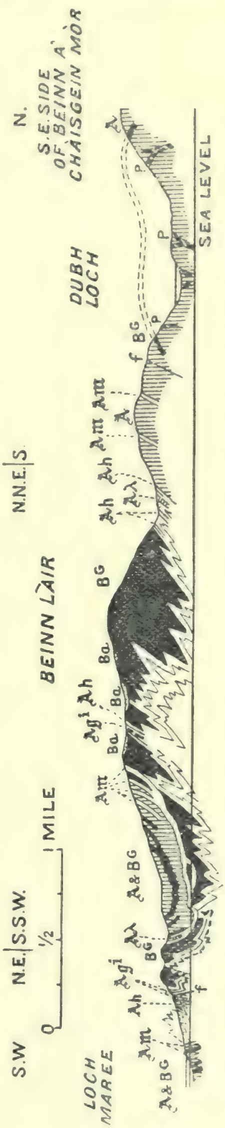


Fig. 1.—Section from near Furnace, Loch Maree, to Beinn a' Chàisgein Mòr.

G = Gneiss of Fundamental Complex. Ag^1 = Graphitic Schist. Ah = Mica-Actinolite-Schist. Aλ = Limestone. BG = Epidiorite and Hornblende-Schist. P = Pegmatite. Am = Mylonised Rocks and Pre-Torridon Crush Lines. Ba = Torridon Sandstone. f = Faults.

---

* The figure is taken from "The Geological Structure of the North-West Highlands," *Mem. Geol. Surv.* (1907), Plate XXX.

movement, the sediments and associated hornblende-schists may have been folded so as to be flanked by the more massive gneisses on either side.

Many broken pieces of the thick hornblende-schists associated with the sediments are found in the mylonites just referred to, and it is certain that these hornblende-schists must have been foliated before the mylonites were formed. There may have been two periods of flexure later than the foliation of these hornblende-schists and separated from one another by an interval during which certain rocks were mylonised. It also seems probable that the movements which plicated the mylonites in the Folais area were later than the broad flexure which affects the basic dykes near Carnmore, for certain mylonites near this place seem unaffected by the flexure.

The Gleann Tùlacha sediments dip steeply away from the massive gneisses on their north-east side, but it is not improbable that they are separated from these gneisses by a thrust-plane. In a section rather less than a mile above the head of Lochan Fada, a pale-grey rock, a few feet thick, comes between the sediments and the reddish gneiss. The grey rock differs from the red gneiss in containing long prisms of hornblende and few or no parallel quartz streaks: the quartz and felspar are granulitic, and the individual grains are in a state of strain, but many of the hornblende prisms have idiomorphic terminations, are quite free from deformation, and contain inclusions of quartz and felspar. In the field it seemed as if the grey rock might perhaps be an altered sediment in which hornblende had been developed by metamorphic action, but possibly it may be a sheared form of the red gneiss. The boundary between the pale rock and the red gneiss is not sharp, but a specimen (4407) of the latter, taken at a distance of two or three feet from the grey rock, is granular rather than granulitic.

A quarter of a mile south-east of Furnace, and also between the headland a mile north-west of Smiorasair and the foot of Abhuinn an Fhasaigh, the mica-schists are separated from the lochside Lewisian rocks by gneiss with many bands of hornblende-schist, most of which certainly represent basic dykes. The line between the gneiss and the mica-schists is a pre-Torridonian dislocation. South-east from the headland referred to, the gneiss and the dykes become more and more crushed as they are traced away from the loch in a north-east direction towards the mica-schists. The gneiss is first crossed by many strings of a compact purplish-brown flinty felsitic-looking material. Then the external aspect becomes affected, the rock weathers white and the flinty material becomes general. The dykes are similarly affected, but to a less extent. Both in the gneiss and dykes the flinty rock can often be seen to follow planes of dislocation. The fault which bounds the gneiss on the north-east side has probably an upthrow to the south-west, but whether the crush phenomena observed in the gneiss are due to this line of movement is doubtful. Perhaps it is a later dislocation along an old line of weakness. About 600 yds. south-east of Smiorasair burn, at a place where a marked feature appears at the north-east margin of the lochside gneiss, the gneiss seems to pass into flaggy brown mica-schist, and the latter might be held to have been formed from the former by mechanical deformation. But perhaps a portion of the schist has been caught on the upthrow side of part of the fault and has been so crushed with the gneiss that the rocks cannot now be distinguished.

The zone of highly sheared schist extending from Beinn Dearg Bheag to Loch na h-Uidhe is possibly of sedimentary origin in part, but the evidence is inconclusive. Its length is about seven miles, and its breadth in some places is 200 or 300 yds., but it is very variable in development, and sometimes consists of several parallel bands at considerable distances from one another, separated by large intrusive dykes which form a great part of the total width of the zone. On both flanks the zone is bounded by gneiss which retains its original coarse characters. The rocks within the zone comprise quartz-rock, quartz-schist, quartz-hornblende-schist, hornblende-biotite-schist, garnetiferous amphibolite, and fine-grained micaceous gneiss. Their appearance, especially that of the finer biotite-schists, is sometimes suggestive of a sedimentary origin, and, as Dr. Teall has pointed out, the association of quartz and hornblende without felspar is unknown in igneous rocks.* In the field, however, the siliceous members of the series often seem to merge into ordinary quartz veins. At Creag-mheall Meadhonach, about a mile and a quarter S.S.E. of Creag-mheall Beag, the hornblende-schist and fine-grained gneiss are in many places penetrated by quartz veins, and also by quartz-rock and quartz-schist, which appear to have been formed by the coalescence of quartz veins and subsequent shearing. Further, at the head of a small burn that flows off the north-east slope of Creag na Sgoinne into Allt Loch Ghiubhsachain, the quartz bands seem to merge into thin quartz veins that traverse the gneiss in all directions. The quartz-hornblende-rocks differ much in composition, and the more siliceous varieties are almost pure quartz. Some rocks within the sheared zone are garnetiferous hornblende-schists, and appear to be portions of the Fundamental Complex. Whether any are of sedimentary origin or not, the rocks within the zone are of special interest, because, unlike most of the sheared pre-Torridon rocks in other parts of the North-West Highlands, they have been sheared before the intrusion of the basic dykes. This is seen, for instance, near the head of the small burn just referred to, where the foliated quartzose bands are well developed along the north side of a dyke of hornblende-schist which clearly crosses the foliation of the bands. Yet these dykes have been locally converted into hornblende-schist, either totally or partially, by renewed shearing movements.

A well-developed linear foliation or rod structure is to be found in the pink gneiss and basic dykes occupying the centre of the Letterewe syncline, a mile and a third S.S.W. from Beinn Làir. In these rodded rocks the constituents are in the form of rods, not laminæ, and sections at right angles to the lengths of the rods show no parallel arrangement. The structure is evidently of secondary origin, and due to causes which have affected diverse varieties of rocks over considerable districts. When the dykes (which are folded) strike N.N.E., the rods are usually almost at right angles to them and incline south-east about 20°. In parts of the syncline the phenomena suggest that the rods may represent portions of foliation planes which have been cut up into narrow strips by strain-slips developed during folding of earlier foliation planes. But in other districts this explanation does not seem satisfactory.*

---

* "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Surv.* (1907), p. 79.

All the shearing and mylonising movements so far referred to are of pre-Torridonian age. It is difficult to be certain of the sequence of events, but there were at least three distinct shearing movements, which are indicated below, beginning with the earliest.

1. Shearing of the quartz-hornblende-schists and other rocks in the Beinn Dearg Bheag and Loch na h-Uidhe zone.
2. Shearing of some of the basic dykes, which was accompanied by intense crumpling and shearing of the rocks of the Fundamental Complex, but did not as a rule lead to any evident folding of the dykes.
3. Folding which produced wide but comparatively gentle folds, such as the Letterewe syncline and the large anticline near Carnmore. These folds plicated the already partly-foliated dykes and led to the further foliation of some dykes which were not already completely foliated. They do not necessarily indicate the disposition of the rocks of the Fundamental Complex, for these rocks were, in many cases, already in a highly contorted condition before the later flexures were developed.

In the above table no mention is made of mylonites—those crushed rocks which still show cataclastic structure as well as partial recrystallisation. Some of those in the north-and-south burn near Folais,† Letterewe, were formed before the Letterewe syncline, but others in the Carnmore district seem later than the Carnmore anticline.

Some of the mylonites are very compact and black, and look so much like flint that they have often been called "flinty crush rocks." East of the burn a mile and 200 yds. S.S.W. of Beinn Làir, a mylonite, about 40 yds. wide, has been formed from an acid gneiss containing basic streaks and lenticles, some of which probably represent dykes. The mylonised rocks formed from the acid gneiss have a conchoidal fracture and are of dark brown or black colour when fresh, but they weather with a dirty white crust, speckled with white or pink "eyes" of felspar. Those stripes which have been produced from the basic streaks are, in fresh fractures, of much the same appearance as the above, but they weather with black or dark brown surfaces. Specimen 4774, from a similar striped mylonite on the west side of the burn, shows under the microscope well-marked augen of felspar in the pale stripes and of hornblende in the dark stripes. Some of the augen show signs of crush. They are surrounded by fine streaks of the cryptocrystalline material, and these streaks are themselves sometimes contorted and crushed by microscopic faults. Mr. Barrow has analysed a portion of this specimen with the following result:—

---

* We may suppose also that rodding can be produced in any cube of rock by subjecting it to equal pressures from four sides in opposite pairs, leaving the constituents to be stretched out towards the other two sides on which the pressure is less (Grubenmann, "Die Krystallinen Schiefer" (1910), p. 106. Dr. Grubenmann states that rodding is characteristic of rocks in the middle limbs of folds, but the evidence in the North-West Highlands is not in accordance with this opinion).

† About a quarter of a mile north from Letterewe.

Silica	60·3
Alumina	15·3
Ferric Oxide	10·7
Lime	5·6
Magnesia	1·3
Potash	1·7
Soda	3·3
Loss on ignition	1·1
	99·3

The percentage of silica must be much higher in some stripes than in others.

Besides these black mylonised rocks which show clear indications of crushing, we frequently find, in or near the mylonised zones, dark brown, grey or black strings, rarely more than an inch thick, which bulge out in rounded projections, or end bluntly and look like intrusive felsites. Such strings are, however, confined to zones which have been crushed, and it seems probable that many of them are isolated on all sides by the adjoining rocks. It is difficult to see how they can be intrusions of true igneous rock, though some specimens that have been sliced bear a close resemblance thereto. Good examples of these felsite-like strings are seen in the wood on the north-west side of Lochmaree Hotel, and just below the summit of Meall Riabhach, Smiorasair. In the latter locality the gneiss may be clear, fresh and granular up to the edge of the veins, but there are dislocations near by. A specimen (4281) of one of the strings shows a microlitic groundmass and signs of fluxion, and the fragments of quartz and felspar included in the groundmass show strongly marked cataclastic structures. Perhaps by the intensity of crushing in some of the mylonised zones sufficient heat may have been generated to fuse small portions of the rock, which then behaved as intrusive veins.*

The post-Cambrian thrusts will be described in Chapter VI., but the character of the large mass of displaced Lewisian Gneiss, of which the southern end lies between Abhuinn an Fhasaigh and Abhuinn Bruachaig (in Glen Logan), may be mentioned here. Its most characteristic rock is a coarse granitoid biotite-gneiss, which in places shows no banding and bears a strong resemblance to parts of the Fundamental Complex near the mouth of the Little Gruinard River. It has not been much deformed, and is quite different from the Lewisian rocks—largely composed of the Loch Maree Series—which are found a little farther west in the unthrust area. The basic dykes in the thrust mass also show their intrusive character perfectly clearly, and have in no case been converted into hornblende-schist,† though all the dykes in the adjacent unthrust area have been so. These striking contrasts may be explained by the difference between the general strike of the larger masses of unthrust gneiss and the direction of movement of the post-Cambrian thrusts, which is considerably nearer west than the strike of the gneiss.

---

* Somewhat similar flinty crush rocks behaving locally as intrusions occur in other districts, for instance, along the circular fault that bounds the cauldron-subsidence of Glencoe. C. T. Clough, H. B. Maufe, and E. B. Bailey, "The Cauldron-Subsidence of Glencoe and the Associated Igneous Phenomena," *Quart. Jour. Geol. Soc.*, vol. lxv. (1909), p. 611.

† Professor Bonney noticed the occurrence of some of these dykes. *Quart. Jour. Geol. Soc.*, vol. xxxvi. (1880), p. 105.

We shall now proceed to describe the main rock types in more detail, taking first those of the Fundamental Complex, next the pre-Torridonian dykes, and, lastly, those rocks which belong to, or are closely connected with, the Loch Maree Series. It will be understood from what has been already said that it is not intended to imply by this order that the Loch Maree beds are the youngest.

THE FUNDAMENTAL COMPLEX.

The portion of the Fundamental Complex most free from foliation and most near its original condition occurs in the northern area near Little Gruinard. Particularly good exposures are found at Cadha Beag,* about a quarter of a mile north-west of Little Gruinard, and portions of these are represented on Plates VI., VII., and VIII. in the memoir on "The Geological Structure of the North-West Highlands." In Plate VI. the darker and paler constituents are very imperfectly separated, and the bulk of the rock may be taken to represent the magma, of intermediate composition, from which more distinctly basic and acid rocks are in process of formation. Another view is to regard the bulk of the rock as a mixture rock, formed by the mingling, probably while in a semi-fluid state, of basic and acid portions. In Plates VII. and VIII. the rock types are more distinct, and the basic and ultrabasic parts are in the form of rounded lumps, chiefly composed of dark hornblende or hornblende-gneiss, which are surrounded and often injected by more acid quartzo-felspathic material. These dark lumps must have solidified before the paler material, and in certain localities it may be seen that some of these lumps must also have possessed a banded structure before the acid material was introduced. Similar basic inclusions are common in many other districts, but are apt to occur sporadically in groups. They vary in size from little kernels up to great lenticles more than a hundred yards long. Some of the larger will be referred to again.

In Plates VII. and VIII. of the above memoir the basic lumps show no clear elongation, but it will be understood that, if a similar rock were subjected to shearing, some deformation and parallel elongation into lenticular forms would be developed. In many districts where the rocks are foliated the smaller lumps are elongated with their long axes parallel to one another and the foliation, but it is a common experience to find the lumps, particularly the larger ones, much less affected by the foliation than the surrounding more acid gneisses. The shearing movements seem often to have proceeded around their margins and to have had very little effect on the main central portions. It must be remembered, also, that in areas which are almost free from granulitic structures and the ordinary indications of shearing, we often find parallel bands and lenticular stripes of basic rock mixed in with the more acid gneisses. The parallelism in these cases may perhaps be attributed to flow motion before complete consolidation.

---

* Not named on the one-inch map.

Occasionally in the northern area, near Little Gruinard and other places, the banding, or broad early foliation of the gneisses, strikes north-east or east-north-east instead of north-west, as is most common. This unusual direction may possibly indicate the original arrangement, for such an arrangement is found in the least altered areas in the Scourie district, one-inch Sheet 107, where it certainly existed before the development of the north-west strike. On the other hand, the Little Gruinard gneisses, unlike those in the Scourie district, show no differences of character which can be connected with the changes of strike. It cannot be asserted that in the former district the gneisses which strike north-west are generally more granulitic than those which strike north-east.

Neither the ultrabasic nor basic rocks are always shown separately on the one-inch map from the more acid, but the localities of some of the more important exposures will be given in the following detailed descriptions:—

Ultrabasic Rocks.—The largest ultrabasic mass in the district is a massive dark hornblende-rock which is situated a little south-west of Little Gruinard. It is nearly two-thirds of a mile in length, trends north-easterly, and, as shown in the one-inch map, is cut almost at right angles by three epidiorite dykes. This mass is penetrated by irregular bands and strings of quartzo-felspathic material which is similar to much of the crude acid gneiss of the district. Masses and lumps of hornblende-rock of the same character as the large mass occur in abundance in the surrounding gneiss, which, near the large mass, has a vertical foliation nearly parallel to the long axis of the latter.

Small masses of dark pyroxenite or hornblendite, and of grey peridotite, appear at several places east of Gruinard River and south of Lochan na Cairill. They include such varieties as olivine-augite-rock (wehrlite) and lherzolite. Between the Inverianvie and Little Gruinard Rivers, also, several bands and oval masses of peridotite and hornblende-pyroxenite make their appearance, often associated with basic rocks containing felspar, which also belong to the Fundamental Complex.

A brown-weathering rock, resembling peridotite, forms eye-like masses in the gneiss on the west side of Loch Fada, two miles south-west of Little Gruinard. The largest is nearly 100 yds. long, and lies more than half a mile from the south end of the loch and 150 yds. from the side.

On the north-east side of Beinn Dearg Bheag, close to the margin of the basic gneiss where it alternates with stripes of acid gneiss, two masses of a soft, unctuous, light-coloured rock make their appearance. The rock is probably chiefly composed of talc or chlorite, together with another light-coloured mineral. Some of it is purple (? penninite), probably from oxidation. The gneiss on each side has a peculiar appearance, probably from the presence in it of some of this mineral.

In a burn a quarter of a mile north-east of Carnmore old house, various lenticles, the largest measuring 10 yds. in length, consist in large part of pale green actinolite. They are of considerable interest, because they contain scales of graphite more than a quarter of an inch long.

A small outcrop of serpentine and peridotite occurs three-quarters of a mile E.N.E. of Eilean Fraoch in the Fionn Loch.

Basic Rocks.—These rocks contain felspar, but are connected with those just described by insensible gradations and occur in a very similar way. The chief varieties in this district are massive and foliated diorites and basic gneisses. In hand specimens they are often indistinguishable from certain dyke rocks, but in field exposures they usually show a more variable composition and many irregular quartzose strings.

Many of the small lumps included in the acid gneiss, in the manner already mentioned in the introductory description of the Fundamental Complex, are of basic character. They are very liable to decompose, and have thus often given rise to small pot-holes in the gneiss which once surrounded them. This is well seen near the Ordnance Station on Creag-mheall Beag, two miles north-west of Loch na Sheallag.

Larger basic masses are very well exposed in the area between Loch na Sheallag and Loch Ghiubhsachain, where they strike north-east or in some direction between north-east and east. All round their margins the gneissose foliation bends so as to conform with them, but, a little distance off the margins, the gneiss strikes north-west, so that they seem to have acted as centres of resistance to the general flow of the acid gneiss, whether this be due to fluxion before solidification or to subsequent mechanical movement. The mass of which the relations are best exposed crops out about a quarter of a mile E.N.E. from the north end of Loch Ghiubhsachain, and forms an irregular oval 350 yds. long by 250 yds. broad. It is a well-foliated, rather evenly-banded hornblende-gneiss.

About 300 yds. north-west of Loch a' Mhadaidh Mòr, a band of fairly well-foliated basic gneiss, 60 yds. wide and crescentic in shape, seems to form a great part of the circumference of a circle of which the centre is a very fresh coarse massive diorite with large white felspars. The diorite lies about 500 yds. north-west of the loch and is 130 yds. long.

A quarter of a mile east of the summit of Beinn Dearg Bheag, one of the lines of intense shearing which have granulitised the acid gneisses subsequently to the intrusion of the basic dykes, passes through a basic gneiss belonging to the Fundamental Complex and converts it into a feathery hornblende-schist.

Basic rocks are well seen near the crag-tops half a mile north-east of Carnmore and on the west and north-west sides of Beinn a' Chàisgein Mòr. In the latter locality the basic material is much mixed with pale-grey acid gneiss, either in broad masses or thin irregular strings, which may cross the foliation of the basic rock. Large basic lumps are also enclosed in the acid gneiss. The felspar is generally subordinate to the hornblende and in smaller grains.

In the centre of the Letterewe syncline, about three-quarters of a mile west of Loch Garbhaig, various bands of hornblende-schist have been mapped which differ somewhat from the normal dyke rocks and may belong to the Fundamental Complex. The margins of some of these have been engraved on the one-inch map.

An evenly-banded hornblende-gneiss with much epidote is often found near the Letterewe limestone, and on the north-east side of the thick hornblende-schist which accompanies this limestone.

Acid Rocks.—The most common type is a pale-grey biotite-gneiss, or augen-gneiss, with felspar augen, chiefly composed of microcline or microperthite, which are sometimes more than an inch long. In various places, as, for instance, Cadha Beag,* near Little Gruinard, and the area between Loch Ghiubhsachain and the north end of Fionn Loch, the acid rock shows no clear foliation and may be regarded as granitic, or almost granitic, both in structure and composition.

On the north side of the highly-sheared belt that stretches from Beinn Dearg Bheag to Loch na h-Uidhe the acid gneiss is less regular in strike than farther south, and generally contains a good deal of muscovite as well as biotite.

Grey acid gneiss with scattered flakes of biotite, or biotite and muscovite, forms the predominant rock in the Fundamental Complex near the south end of the tract between Eilean Fraoch (Fionn Loch) and Lochan Féith Mhic'-illean. The early banding elsewhere recognisable as having been in existence before the intrusion of the basic dykes is here very often obscure, and perhaps in some places never existed. The later foliation, however, corresponding to that in the basic dykes is generally strongly developed. It usually strikes W.N.W. and dips steeply in a N.N.E. direction, parallel to the axial planes of many folds. Examples of the felspar augen are particularly well seen in a crag about half a mile south-west of Lochan Cnapach, three miles east of Fionn Loch.

A fine flaggy micaceous granulitic gneiss which has been formed from a more massive gneiss by shearing movements subsequent to the intrusion of the basic dykes, passes a little north-east of Càrn na Béiste, about a mile from the north margin of the map. It strikes north-west. A flaggy gneiss similar to and perhaps continuous with the above passes about half a mile west from the foot of Lochan Gaineamhaich. Other bands of granulitic gneiss, formed by similar shearing, are seen in the two following localities: 30 yds. north from the Cadha Beag road, a quarter of a mile north-west of Little Gruinard; east of the Inverianvie River, between Càrn an Lochain Duibh and Lochan Giubhais. In the second locality the band has been much folded after being sheared. The above bands all strike north-west, approximately parallel to the general direction of the basic dykes. Other somewhat similar, but perhaps later-formed, bands have a nearly east-and-west course. A band with this direction passes, for instance, 100 yds. south of Càrn nam Buailtean, east of the Gruinard River, and can be traced more than half a mile in a westerly direction, crossing several dykes which are bent out of their course and foliated.

The broad anticline at Carnmore is best indicated by the folded crop of the dyke near the Dubh Loch, but also by the different directions of dip of the foliation commonly observed in the acid gneiss. Most of this gneiss is more granitic than granulitic in structure, but it includes a zone in which the foliation is finer than usual, and wherein the structure may be partially granulitic. This zone keeps at the side of the folded dyke for more than five miles.

---

* See Plates VI., VII., VIII., "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Surv.*, 1907.

It contains more quartz veins than the gneiss farther off the dyke, and shows various thrust-like lines parallel to the dyke. It probably became finely foliated in consequence of movements which took place near the dyke before it was folded into its present form.

The north-west part of the thrust gneiss in the centre of the Letterewe syncline is chiefly composed of an acid gneiss with biotite and felspar augen. The gneiss at Meall Riabhach at the south-east end of this thrust mass is a regularly banded acid gneiss without the lenticular wavy structures which are common in the strip of gneiss along the lochside between the headland north-west of Smiorasair and the foot of Abhuinn an Fhasaigh. It is as a rule granitic rather than granulitic, but displays strong indications of cataclastic action in certain parts (4280).

PRE-TORRIDONIAN INTRUSIONS.

The most important intrusions are the basic dykes striking north-west, but another series of dykes, of rather more basic composition than the above, is also well developed in the northern area between Little Gruinard and Beinn Dearg Bheag. The last-mentioned dykes, which may be called the "green dykes" from their general olive-green tint, strike as a rule nearly east and west, but must be distinguished from the east-and-west picrite dykes of the Lochinver district, one-inch maps 101 and 107, which are later than the north-west basic dykes, while the "green dykes" are for the most part older than the latter. The "green dykes" are basic amphibolites consisting mainly of acicular green hornblende, with some chlorite, but often nearly free from felspar. They have been classed with ultrabasic dykes in this district. One partially foliated syenite dyke has been found, and near Carnmore and Coppachy there are a number of pegmatites which are believed to be later than the basic dykes.

Ultrabasic Dykes.—Half a mile south of the outlet of Lochan na Bearta a dark green foliated ultrabasic dyke has been traced for about three-quarters of a mile. For most of its course it closely follows a thick dyke of hornblende-schist, but diverges near the south-east end. The rock, being of a more perishable nature than the contiguous schists, has given rise to a slack or valley. There is evidence that the intrusion is later than the contiguous hornblende-schist. Another, or possibly the same, dyke is seen farther east, a mile and a half S.S.E. of Beinn Dearg Mhòr. In the displaced mass of gneiss about three-quarters of a mile north of the Heights of Kinlochewe a few small dykes of sheared ultrabasic rock, at present in the form of unctuous schist, have been noticed. They are only a little below one of the great post-Cambrian thrust-planes.

The "green dykes" are most numerous south of Creag-mheall Beag and Loch a' Mhadaidh Mòr. They are comparatively soft, weather rather like the other ultrabasic dykes, and frequently contain large plates of biotite. In direction and thickness they are more irregular than the other dykes, but the general strike is nearly east and west. They are coarse and quite massive at the centre and not very schistose even at the margins. The margins are chilled and show clear intrusive junctions, which prove that they belong to real dykes and not basic knots, such as are so frequently found in the Fundamental Complex.

Basic Dykes.—The north-west dykes, though numerous, are by no means evenly distributed. On the eastern and southern slopes of Beinn a' Chàisgein Beag they occupy nearly as much ground as the gneiss, while, on the other hand, certain belts are comparatively free from them. Some of the larger examples are more than 100 yds. wide, and adjacent dykes which run nearly in the same direction occasionally combine and form even broader masses. Many of the dykes form projecting outcrops, but others weather into hollows or slacks, as near Loch an Iasgair, three and a half miles S.S.W. of Little Gruinard. In the northern part of the district, for a width of three miles or more, all the dykes are massive epidiorites except in a narrow zone of shearing, where they have been converted into hornblende-schist, like the dykes near Scourie described by Dr. Teall.* Consequently in this northern area the evidences of intrusion are very abundant and clear. This is also the case, as already stated, in the gneiss of Glen Bruachaig (Glen Logan), which has been carried forward by the post-Cambrian movements. Plate II., in the memoir on the "Geological Structure of the North-West Highlands," representing a portion of this displaced mass, shows two of these epidiorite dykes intersecting the rudely foliated gneiss near the Heights of Kinlochewe. At Cadha Beag, a quarter of a mile north-west of Little Gruinard, and again near Beinn Dearg Bheag, the gneisses of the Fundamental Complex strike north-east nearly at right angles to the dykes. In the above areas the dykes are approximately vertical, but south of the quartz-hornblende zone the dykes are usually in the form of hornblende-schist and incline to the north-east nearly parallel to the prominent foliation in the gneiss.

Even in the well-foliated dykes the form of some of the original minerals is still preserved. Thus between Loch Garbhaig, north of Slioch, and the north-and-south burn rather more than a mile west of that loch, various bands of hornblende-schist contain porphyritic forms composed of granules of felspar. One of these bands, about 1000 yds. W.N.W. of the outlet of the loch, is composed of different layers, some of which show the porphyritic forms, often about half an inch long, so crowded together as to equal in bulk the rest of the rock, while other layers contain hardly any. Again, about 1000 yds. north-east by north of Furnace, certain parts of a hornblende-schist are full of porphyritic forms of felspar, giving lath-shaped and squarish sections. Near the sides and along certain bands in the interior these forms have been sheared out into thin parallel streaks.

In most of the foliated dykes the foliation is parallel to the sides. The margins are more closely foliated than the interior, and, in the broad dykes, are often finely schistose, while the central parts remain in a massive condition. That the foliation is so often parallel to, and most perfectly developed near, the margins, is, no doubt, due to the fact that most of the shearing movements have in this district proceeded along the dykes. These movements have often had comparatively little influence on the contiguous gneiss.

A large dyke, which contains free quartz, and appears to be more acid than the usual type, crosses the south part of Loch Fada, on the west side of Little Gruinard, and continues E.S.E. past Lochain Cnapach.

---

* "The Metamorphosis of Dolerite into Hornblende-Schist," *Quart. Jour. Geol. Soc.* vol. xli. (1885), p. 133.

A little north-east of Beinn a' Chàisgein Mòr certain foliated dykes contain such abundant inclusions of pale-grey acid gneiss that they can be readily distinguished and traced. From the evidence obtained it seems probable that most of these dykes are earlier than the neighbouring dykes without inclusions. A good example of one of these dykes, in which the lenticular inclusions form perhaps half the mass, may be seen 300 yds. W.N.W. of the south end of Lochan Cnapach.

Some of the foliated dykes in the gneiss in the centre of the Letterewe syncline still show their original intrusive character distinctly. This is seen best about half a mile west and half a mile south of the outlet of Loch Garbhaig. These dykes are distinctly foliated, and some of them strike north-east for several hundred yards and are inclined at gentle angles. In addition to the above, all or nearly all the foliated dykes which occur near the Dubh Loch of Carnmore and Sròn a' Choit, west of the Lochmaree Hotel, must have been foliated before they were plicated, for the foliation planes share in the folding of the outcrops.

The folded dyke 700 yds. E.S.E. of the head of the Dubh Loch of Carnmore dips gently north-east and contains a quartz vein, from 12 to 20 ft. thick, which is almost parallel to the base, and lies rather nearer the base than the top. The portion of the dyke above the vein consists of hornblende-schist with foliation planes parallel to the top of the band, but the part below is biotite-actinolite-schist with disturbed foliation planes dipping steeply south, so that it is clear that the quartz vein occupies a plane of discordance. In addition to the quartz, the vein contains scattered hornblende crystals, streaks of biotite-actinolite-schist, and irregular patches, as much as a foot thick, of a coarsely crystallised carbonate which contains some diopside. It is suggested that the schist below the vein may once have been in the form of hornblende-schist like that above, but that the movements along the vein have converted some of its hornblende into biotite, and in doing so have set free some carbonate.

Syenite Dyke.—About a third of a mile south-east of Carnmore old house a coarse-grained dyke, from 5 to 8 ft. thick and chiefly composed of hornblende and microcline, can be traced for 160 yds. in a N.N.E. direction. Some parts are massive, but others, particularly on the south-east side, are foliated parallel to the margin.

Pegmatites.—Pegmatites, which are believed to be of later age than the basic dykes, are abundant near the Dubh Loch of Carnmore, and narrower bands are also common near Coppachy, Loch Maree, but are generally in a mylonised condition. The unfoliated pegmatites are harder than most of the rocks in which they occur and often form prominent exposures or crags in areas which are to a considerable extent covered with drift. Many of them are rather irregular in direction and give off short branches, but near Carnmore the general trend is perhaps north-west, irrespective of the foliation of the gneiss which they traverse. In the crags 1500 yds. south of Carnmore, where the strike of the gneiss varies between east and north-east, the transgression across the foliation is quite clear.

The Carnmore pegmatites are frequently found quite free from foliation even in places close to well-foliated dykes of hornblende-schist, and in the adjoining one-inch map 91 similar unfoliated pegmatites frequently cross foliated dykes. The common constituents of the unfoliated pegmatites are plagioclase, orthoclase and microline felspar, quartz, biotite and muscovite. In the crags north-east of Carnmore muscovite often occurs in idiomorphic crystals from 1 to 3 ins. long and from a ¼ to 1 in. broad, measured across the basal cleavage. In the tumbled blocks from a white pegmatite a mile and 200 yds. west of south of Carnmore some of the mica plates are 10 ins. long and 3 or 4 ins. broad. In most of the pegmatites, both near Carnmore and Coppachy, white felspar is more common than red. North-east of Carnmore the white felspar is sometimes enclosed within the red. Graphic intergrowths of quartz and felspar have been noticed in the crags south, north and north-east of the same place.

No pegmatites show clear evidence of folding, but the movements which plicated many of the mylonised rocks in the Letterewe syncline are probably later also than the pegmatites. Mylonised pegmatites are common, but, excepting near Coppachy and Smiorasair, are rarely more than a foot or two thick: at the former place they have more often been mylonised than the adjacent rocks, and the mylonised examples contain numerous eye-shaped pieces of pink or white felspar, some of them as large as a hen's egg, in which one cleavage plane crosses the entire breadth. Crystals of such a size are rare in any of the other Lewisian rocks. Most of the pieces have rounded outlines, and look like corroded phenocrysts embedded in a streaky pale-grey or greenish-grey felsitic matrix. The subparallel streaks composing the matrix vary in translucency, and are often so thin that thirty can be counted in the thickness of half an inch. They wind round the felspar augen and are sometimes sharply folded.

The greenish fine-grained rock 50 yds. north-east of the mica-schist on the south-east side of Smiorasair is probably a mylonised pegmatite. It is hard, sharply jointed, very fresh, weathering only in a dirty white film, and possesses a conchoidal fracture. Microscopic examination shows the matrix to be cryptocrystalline and the grains in it to be composed of felspar and epidote. The felspar sometimes shows plagioclase striation and gives definite extinction. An analysis of the rock by Mr. Barrow gave the following result:—

Silica	72·90
Alumina	13·85
Ferric Oxide	1·85
Lime	1·17
Magnesia	0·72
Potash	5·21
Soda	2·49
Loss on ignition	1·50
	99·69

THE LOCH MAREE SERIES AND SOME ASSOCIATED SCHISTS.

The distribution and general relations of these beds have been dealt with in the introduction to this chapter. Tourmaline is not uncommon both in the mica-schists and in veins in the thick hornblende-schists which are associated with them. These veins must have been in existence before the formation of some of the mylonised rocks in the Letterewe syncline. In the more detailed description of lithological characters, etc., which now follows, the rocks will be taken in the following order:—

(1) Mica-schist; (2) Mica-actinolite-schist; (3) Graphite-schist; (4) Kyanite-gneiss; (5) Granular quartz-rock; (6) Quartz-schist and quartz-magnetite-schist; (7) Quartz-hornblende-schist; (8) Limestone; (9) Calcareous biotite-hornblende-schist; (10) Chlorite-schist; (11) Hornblende-schist and hornblende-chlorite-schist; (12) Hornblende-schist with brown mica and pyrites.

No further description will be given of the rocks in the highly-sheared zone between Beinn Dearg Bheag and Loch na h-Uidhe.

1. *Mica-Schist.*—The flaggy brown mica-schist which so closely resembles the Findlater Castle rock of Banffshire is not so common on the north side of Loch Maree as in Gairloch. We often find, instead, bands which are of a rather more siliceous type or which are so intimately mixed with thin seams of graphite-schist that they can hardly be separated. No clastic grains have been detected in any of the beds. A broad band of the somewhat siliceous mica-schist runs for about three miles close to the path that leads from near Letterewe in a south-east direction, and other exposures occur at the side of the thick hornblende-schist east of Furnace and near Coppachy. These schists weather with a pale-grey crust and often project somewhat from the other associated mica-schists. Fractures across the foliation are conchoidal, and present a somewhat vitreous lustre.

In Gleann Tùlacha a dark brown foliated rock is seen on both sides of the limestone in the burn two-thirds of a mile above the head of Lochan Fada, also in a section rather less than a mile above the head, and in other places. It is less flaggy and more felspathic than the Findlater Castle schist, and contains epidote crystals, sometimes half an inch long, as well as calcite in certain bands. Biotite is generally in considerable excess of white mica, and small grains of black iron-ore and prisms of tourmaline can often be seen with the unaided eye. In the section rather less than a mile above Lochan Fada the mica-schist is irregularly mixed with a peculiar coarse gneissose rock, of uncertain origin, which contains large crystals of green actinolite, epidote, pink and white felspar and quartz. The dark and pale constituents are often separated into sub-parallel folia, and the actinolites in the acid parts are sometimes arranged in radiating groups as much as an inch in breadth. The mica-schist often occurs in parallel bands with the gneissose rock, but, in some places, parts appear to be included in this rock. It sometimes shows a structure, resembling bedding, which is crossed by a foliation parallel to the banding in the gneissose rock.

The more micaceous or pelitic mica-schists never spread over large areas, and they have not been separated from the others. They often contain many garnets, as may be seen on the shore of Loch Maree, 150 yds. slightly west of south of Inishglass, and also in the burn running south-east across the Lewisian inlier on the east side of Slioch. The schist in the last locality has a silvery lustre, and the matrix is composed almost entirely of colourless and pale-green mica, reddish-brown biotite and epidote.

Owing to the fineness of grain it is often difficult to discern to what extent the mica-schists have been mylonised, but microscopic examination shows that in various places the granulitic constituents have been strained and crushed down into streaks of still finer material. Some of the brown flaggy schists on the south-east side of Beinn Airidh Charr should perhaps be regarded as mylonites, in the composition of which other rocks share as well as mica-schists. Near the south-west side of the thick hornblende-schist a mile south-east of the hilltop, the brown schist contains lenticles and eyes of hornblende-schist like those of the thick band. Many of the lenticles are 2 or 3 ft. long, and their folia end abruptly at the margins, while the folia of the brown schist wind round the margins.

2. *Mica-Actinolite-Schist.*—Mica-schists with brown mica and needles of actinolite are not uncommon. Accessory constituents frequently found are garnet, pyrites and some ferriferous carbonate, in irregular streaks. The pyrites is often in sufficient abundance to give a rusty colour to weathered surfaces. Schists of this type form a considerable proportion of various bands which run from near the top of Beinn Airidh Charr towards the west end of Loch Garbhaig. Examples may also be seen in the burn that flows into Loch Maree half a mile east of Isle Maree, and at the edge of the thick hornblende-schist rather more than two-thirds of a mile slightly south-east of Furnace.

While in some of these schists the hornblende crystals are small and sparse, in others, only a few yards distant, they may be half an inch thick and two inches long, and may preponderate over the matrix, combining into radiate forms with arms nearly parallel to the foliation. Microscopically they are dark green or black, but in thin slices often nearly colourless and evidently crowded with small granulitic inclusions. Most of the garnets have round edges or occur in lumps with the long axes parallel to the foliation. In the band three-quarters of a mile south-west of Beinn Làir, the large garnets have round outlines and coats of biotite, while the smaller have no such coats and are idiomorphic.

The calcareous seams in these schists vary from the thinnest streaks up to bands a foot or two thick. They often cross the foliation or enclose rounded pieces of schist. In a thin band within the thick hornblende-schist half a mile south-west of Meall Mhèinnidh, the transgressive appearance of the calcareous streaks and the inclusion of hornblendic lumps within them are well seen. Some of the hornblendic lenticles appear to have been derived from a schist which was first sharply folded and then broken along the limbs of flexure. A considerable part of the calcareous matter appears to have been introduced into its present position either at the time of, or subsequently to, various thrusts and mylonising movements. The rocks were probably originally calcareous, and the ready solubility of the carbonate enabled it to travel from one part of the rock to another, and to collect in the lines of thrust.

3. *Graphite-Schist.*—This type usually forms thin bands, from a few inches to a few feet thick, which are mixed with mica-schist or mica-actinolite-schist. At a locality nearly a mile south-west of Beinn Làir a dozen laminæ of more or less graphitic schist are some-

times visible in the breadth of half an inch. The graphite-schists and the intermixed mica-schists often weather with a rusty colour in consequence of disseminated pyrites. Nearly all the rusty schists between Letterewe and Smiorasair contain graphitic bands, and, including thin hornblende-schists, they form an outcrop between 300 and 450 yds. wide, which lies between hard siliceous mica-schists on the south-west side and a thick hornblende-schist on the north-east. Bands of graphite-schist also occur north-west of Loch Garbhaig, S.S.W. of Beinn Làir, in Gleann Tùlacha and other places.

In many localities, for instance, in the burn a quarter of a mile north-east of Furnace, the graphite-schist is so full of "black-leaded" planes of movement that no clean fracture can be procured though the adjoining schists are but little crushed.

The graphite in these schists never occurs in distinct scales, but in irregular shreds and small patches, which sometimes exist as inclusions in other minerals. These inclusions prove not only that the graphitic rocks existed as schists, but also that these schists had been contorted and crushed before the formation of the minerals which contain the graphite. One of the enclosing minerals is actinolite in feathery and radiate forms. This is seen well in slice 4427, obtained from a hard graphite-schist that rings under the hammer, 1500 yds. S.S.E. of Beinn Làir. A schist a mile and 300 yds. W.N.W. of the head of Lochan Fada contains a white mica which must have been developed after the parallel arrangement of the chief graphitic portions. In a microscopic section, 4421, from this locality, there are also various patches of felspar, often twinned, and a mineral supposed by Dr. Teall to be probably andalusite, which is of later origin than the present distribution of the graphite.

4. *Kyanite-Gneiss.*—Three bands of kyanite-gneiss have been noticed near Carnmore (head of Fionn Loch). They strike north-west, and are all more than a mile and a half north-east of the nearest sediments in Gleann Tùlacha. The band east of the old house has been traced for a quarter of a mile, dips north-east about 45°, and varies in thickness from 16 to 20 ft. It is pale-grey in colour and rather coarser than the contiguous gneiss, which is reddish and contains subparallel streaks of colourless quartz. In the landscape, however, the kyanite-gneiss generally appears dark, probably on account of the roughness of the weathered face. The foliation in the immediately adjacent reddish gneiss dips the same as in the kyanite-gneiss, but farther off it becomes more irregular, and it is suggested that possibly the latter band may occur along a plane of movement. The kyanite crystals, sometimes 2 ins. long, usually project on the weathered face and have their long axes rudely parallel to the biotite flakes and the margin of the band, One variety of the rock contains little else but kyanite and biotite, the latter in large crumpled plates half an inch long, together with quartz veins which include unusually large kyanites. In the more common type quartz is abundant, and both oligoclase and orthoclase also occur.

5. *Granular Quartz-Rock.*—Three-quarters of a mile E.N.E. of Inishglass (north-east shore of Loch Maree), and also three-

quarters of a mile E.N.E. of Furnace, some bands of granular quartz-rock, rather resembling quartzite, have been observed. It is to be noticed, however, that dark hornblendic lumps are occasionally found within this rock, and that their folia are crossed by its laminæ. It seems to follow that if the quartz-rock is an altered sediment it must nevertheless at one time have been made to flow like an intrusive rock.

6. *Quartz-Schist and Quartz-Magnetite-Schist.* — Most of the quartz-schists in this district, whether with or without magnetite, appear to have been mylonised. They are more compact and more finely banded than those in Gairloch (Sheet 91), and have a considerable resemblance to altered chert, but this appearance is perhaps due to shearing. Most of the bands are only a few feet thick, and so much contorted and faulted that they are difficult to trace. Bands with dark-grey or black streaks and resinous lustre are seen at the following places: the hillside 350 yds. north-east of the outlet of Loch Garbhaig; a third of a mile E.S.E. of Letterewe; nearly a third of a mile E.N.E. of Inishglass; a third of a mile N.N.W. and 350 yds. slightly west of south of Coppachy; and behind the rock called Tòrr an Fhithich about half a mile north-west of Smiorasair. At the second, third, fifth and last localities the schist contains small pieces of actinolite and is closely associated with actinolite-mica-schist. At the second, fifth and last localities magnetite is certainly present. Specimen 4664, from Tòrr an Fhithich, was examined by Dr. Teall and found to contain quartz, magnetite, ferric oxide and a mineral which forms small, slender prisms, possibly sillimanite. The magnetite forms compact streaks or lenticles, and, more rarely, detached idiomorphic crystals. A partial analysis gave the following result:—

Silica	90·30
Ferric Oxide and Alumina	8·50
Loss on ignition	·02
	98·82

No importance must be attached to the relative proportions of silica and iron. It would be possible to select specimens in this group of rocks which would consist of almost pure quartz or pure magnetite.

In the Lewisian inlier on the east shoulder of Slioch, a thin wedge of altered sediments in Abhuinn an Fhasaigh includes a granulitic quartz-magnetite-schist, 4320, which contains a mineral supposed by Dr. Teall to be sillimanite. If this supposition be well founded it suggests that the rock may have suffered from contact metamorphism, perhaps induced by the igneous rock which is now represented by the Beinn Làir hornblende-schist.

Some of the quartz-schists appear to have been produced by the shearing of quartz veins. The hornblende-schist a mile N.N.E. of Isle Maree is traversed by a folded quartz-schist about 12 ft. thick, containing a good deal of pyrites, and also by thinner veins of similar schist.

7. *Quartz-Hornblende-Schist.*—A few bands of quartz-hornblende-schist have been noticed in the Beinn Làir hornblende-schist. About half a mile south-east of the hilltop two such bands, 2 and 5 ft.

thick respectively, are separated by 16 ft. of fine hornblende-schist. They contain crystals of dark green actinolite, some of which are 3 or 4 ins. long, and combine into radiate forms. Idiomorphic garnets, half an inch in diameter, occasionally occur in some micaceous portions. The quartz is usually subordinate in amount to the actinolite, and occurs in granulitic streaks edging that mineral. In a thin slice, 5109, the actinolite is seen to contain many inclusions of quartz. A band of similar schist, about 20 yds. wide, is seen a little more than two-thirds of a mile south-east of the top of Beinn Làir.

8. *Limestone.*—The Letterewe Limestone has long been known,* and was formerly quarried on the west side of the burn 200 yds. north-west of the ruined house of Folais.† The limestone and the accompanying calcareous beds appear repeatedly in the burn north of the quarry for about 700 yds., the exposures being separated by finely-foliated hornblende-schist, like that of Beinn Làir. Here the rocks occupy the apex of a compound syncline, the axial planes of which strike north-west. In some exposures the thickness of the limestone is about 21 ft. South-east of Folais, in the south-western limb of the syncline, the limestone and calcareous beds can be traced for nearly three miles, but they form only a thin outcrop, and are much interrupted at the south-east end by lines of movement. Along the north-east limb of the syncline the horizon cannot be traced as far as a mile.

In the quarry the limestone is compact and creamy, and contains lumps of green actinolite. Some of the bands contain more biotite, chlorite and hornblende than carbonate, and also thin streaks of white talc (?). Some of the actinolite lumps are 2 or 3 ins. in diameter, and all have smooth round surfaces coated with flakes of biotite, chlorite and white mica. In cross-sections some of them show centres from which the actinolite crystals have grown out in diverging rays, while many others are broken by small faults.

A soft greenish rock which appears to be a calcareous mylonite in a plane of movement is seen between the thick limestone and the hornblende-schist on the east side of the burn near the end of the old tramway. It is finely striped, and contains many inclusions with their long axes parallel to the striping. Among these inclusions have been noticed lumps of limestone, round pieces composed of actinolite fibres, rounded pieces of quartz-tourmaline vein-stuff, and scattered prisms of tourmaline.

All the impure calcareous rocks which accompany the thick limestone seem to be mylonised, but they are not all of the type of the green rock described. The mylonised rock in the burn two-thirds of a mile slightly west of north of Folais includes no lumps of radiate actinolite, but many small pieces of finely-foliated hornblende-schist. The plane of junction between the mylonised rock and the thick hornblende-schist is often a crush line, at the side of which the foliation planes of the hornblende-schist are truncated, and it seems certain, consequently, that this schist has contributed material towards the formation of the mylonite. In the burn two-thirds of a mile slightly west of north of Folais, besides the pieces of hornblende-schist, fragments of a slightly calcareous dark-grey mica-schist, rich in biotite, appear in the crushed material.

---

* It is indicated in Macculloch's Geological Map of Scotland, and described by Sir R. I. Murchison and Sir A. Geikie in their paper "On the Altered Rocks of the Western Islands of Scotland, and the North-Western and Central Highlands," *Quart. Jour. Geol. Soc.*, vol. xvii. (1861), p. 171.

† Not named on the one-inch map. About a quarter of a mile north of Letterewe.

The Gleann Tùlacha Limestone may possibly be on the same horizon as the Letterewe bed, but in a different limb of fold. It differs considerably in appearance, but this is perhaps mainly due to the great amount of deformation the limestone at Letterewe has undergone. A good exposure of the Gleann Tùlacha bed is seen rather less than a mile W.N.W. of the head of Lochan Fada. The fresh rock is almost white, but the weathered face is brownish, and is crowded with projecting fibres of pale green tremolite arranged in fans or radiate forms. Individual fibres of this mineral penetrate far into the matrix, and show no signs of crushing. Those of longest dimensions lie along parallel planes, and give rise to a banded appearance. A "train" of boulders of a very similar limestone extends in a south-westerly direction from the south side of Lochan Fada a mile and a half below the head, so that it is probable that the limestone crop extends in a south-easterly direction in the bed of the loch for a considerable distance. About 300 yds. W.N.W. of the good exposure referred to, a boulder of limestone was observed to be crowded with prisms of pale-green augite, but this mineral has not been found in the limestone *in situ*.

Limestone appears in various localities just at the north margin of the Beinn Làir hornblende-schist. On the north side of Meall Mhèinnidh four bands of limestone or calcareous rock can be observed; the bottom band contains streaks and lenticles of limestone embedded in a chloritic or micaceous schist which overlies gneiss. In one of the exposures in the burn W.N.W. of Beinn Airidh Charr the limestone contains reddish streaks, represented in specimen 3471, which owe their colour to the presence of crystals of reddish-brown rutile: a plagioclase felspar and quartz are also present. In a second exposure in the locality the rock consists of almost pure white saccharoid dolomite which gives more than 96 per cent. of mixed carbonates of lime and magnesia, as is shown by the following analysis:—

Insol	1·35
SiO_2	·06
Al_2O_3	·09
Fe_2O_3	·97
FeO	·45
MnO	·35
CaO	32·80
MgO	21·01
CO_2	42·55
	99·63

In striking contrast to the last rock, another exposed farther east contains many silicates concentrated along certain layers which perhaps represent bedding. The original rock was probably a cherty carbonate. It effervesces freely with cold dilute HCl, and the analysis of one of the purer calcareous bands shows that it has only been partially dolomitised. The analysis, which was executed by Mr. J. S. Grant Wilson, is as follows:—

Insol.	9·57
SiO_2	·13
Al_2O_3	·16
Fe_2O_3	1·44
FeO	1·42
MnO	·36
CaO	34·25
MgO	11·75
CO_2	40·65
	99·73

Sp. Gr. 2·78

The insoluble portion consisted mainly of silica, which is recognisable in the thin slice as microcrystalline quartz.

9. *Calcareous Biotite-Hornblende-Schist.*—Some of the limestones are flanked by calcareous schists or calcareous gneisses, in which biotite, or a green mica and hornblende, seldom radiate, occur in abundance. About a third of a mile E.S.E. of Folais, a calcareous biotite-hornblende-gneiss occurs 50 or 70 yds. north-west of the Folais calcareous horizon, and is flanked by more acid gneiss on both sides.

10. *Chlorite-Schist.*—Bands composed almost entirely of chlorite are seen in the following places: a quarter of a mile south-east of Furnace, the burn by the road about a mile and a quarter north of Letterewe, and the more easterly of the two burns three-quarters of a mile N.N.E. of Isle Maree.

11. *Hornblende-Schist and Hornblende-Chlorite-Schist.*—The hornblende-schists occupy a much larger area than the sediments with which they are associated. The most prominent band forms the mountain masses of Beinn Làir and Beinn Airidh Charr. On the latter hill hornblende-schist is exposed continuously for a distance of two miles across a synclinorium, with axial planes striking north-west. The base of the band changes its course in the north-west side of the hill and curves southward to Loch Maree, while the hornblende-schists in the south-east slopes are repeatedly folded with a band of mica-schist.

There can be little doubt that the hornblende-schists now under consideration were originally intrusive igneous rocks. Their general uniformity of composition and the absence of inclusions are inconsistent with the supposition that they are altered subaerial lavas. On the other hand, they have nowhere been observed to transgress the sediments. South-east of Letterewe one of the hornblende-schists keeps close to a thin band of siliceous mica-schist for nearly a mile. A similar want of evidence of intrusion is, however, also found at the sides of dykes which have been sheared and dragged to an unusually great extent.

It is improbable that these schists are older than the basic dykes, for they are never seen to be intersected by them, even in areas where the adjoining gneisses repeatedly are. Possibly they represent intrusive sills which were fed by the dykes. Before the dykes were foliated the gneiss probably contained but few divisional planes, and a mass of molten rock which had come up through it in vertical fissures might, perhaps, on reaching the sediments, find more ready passage between the bedding planes and take the form of sills.

The most common type of these hornblende-schists is more finely foliated than most of the dykes. Parallel to the foliation we can often discern thin laminæ of different colours, black, dark-green or dirty-white. These laminæ may possibly have been derived from parts which differed originally, or they may be due to segregation proceeding during shearing. Garnets are abundant in certain places, and are often bordered with granules of white felspar. In this one-inch map no parts have been observed free from foliation, though in the Gairloch district, in one-inch map 91, the central parts of the broader bands are sometimes so. On the other hand, the shivery chloritic type, which is also often slightly calcareous, is rarer than in the Gairloch area.

Thin zones in which the hornblende forms "augen" may be seen in the Beinn Làir schist half a mile slightly north of east of the foot of Loch Garbhaig, a third of a mile slightly north of west of Beinn Làir, and at other places. An exposure by the east side of a small burn rather more than three-quarters of a mile east of the head of Lochan Fada shows a good many imperfect lath-shaped sections of felspar about half an inch long.

On Beinn Làir and Meall Mhèinnidh certain zones containing lenticles of dirty-white saussurite may be noticed at frequent intervals from a third of a mile E.N.E. of the top of Beinn Airidh Charr to three-quarters of a mile S.S.W. of the head of Lochan Fada. One of the best exposures, represented in Plate XXVIII. in the Memoir on "The Geological Structure of the North-West Highlands," is 200 yds. east of the path nearly two miles N.N.E. of Letterewe pier. Here a considerable number of the lenticles are more than a foot long, and some exceed three feet. Their long axes are parallel, and indicate a direction of stretching which is nearly at right angles to the strike of the foliation. The lenticles vary greatly in abundance in different localities, and in some places are very sparse; indeed one example was found isolated 60 yds. from any other, a mode of occurrence hardly explicable on the supposition that the lenticles have been produced by the breaking up of a once continuous band. More probably they represent segregations which existed in the rock before its conversion into schist. Originally they may have been nearly spherical; occasionally, indeed, as in a locality a third of a mile slightly east of south of the head of Lochan Fada, examples give nearly circular sections.

Many of the thin quartz veins in the hornblende-schist contain tourmaline in very thin needles, which are often combined into sheaves. It usually forms only a small proportion of each vein, the rest consisting of quartz, or of quartz, axinite and epidote. Such veins are well seen on Meall Mhèinnidh, from 150 yds. west of the top to rather more than a quarter of a mile south-east, also 700 yds. south-east of the long island in Loch Garbhaig, where some of the tourmaline needles are an inch long. The fragments of tourmaline vein-stuff which occur in the calcareous mylonised rocks already described may well have been derived from similar veins.

Near Torridonian rocks the hornblende-schists are often crossed by thin epidotic strings, and the foliation planes and the sides of the veins of quartz and pegmatite are also stained with hæmatite. The pebbles in the basal Torridonian breccias are sometimes crossed by epidotic strings, which, as they do not pass into the matrix, must have existed in the Lewisian rocks before the formation of the breccias. They were doubtless formed in pre-Torridonian times by decomposition near the rock-surface.

12. *Hornblende-Schist with Brown Mica and Pyrites.*—Many of the thin bands of hornblende-schist which occur within the area chiefly occupied by the altered sediments, closely resemble portions of the actinolite-mica-schists. They contain calcareous streaks, brown mica and pyrites, together with hornblende crystals which are frequently grouped into radiate forms and are of a stouter build than those usually found in the thick bands. The thin bands of hornblende-schist in the mica-schist half a mile E.S.E. of Coppachy are of the finely-foliated type, so common in the thick bands, and probably some, if not all, of them represent folded and faulted portions of these bands. Many of the other bands farther west, likewise most of the thin bands between Coppachy and Letterewe, and half a mile W.N.W. of Coppachy, belong, entirely or in part, to the type of schist under description. Specimen 4773, obtained from the side of Loch Maree 350 yds. west of Inishglass, proved on microscopic examination to be in a mylonised condition: one portion with rounded outline and less calcareous than the rest is composed of hornblende-schist of the finely-foliated type. In Gleann Tùlacha pyritous hornblende-schists appear again near the base of the Beinn Làir hornblende-schist in several places.

C. T. C., W. G., E. G.

CHAPTER IV.

THE TORRIDON SANDSTONE.

General Descripton.

Reference has been made in a previous chapter (p. 9) to the uneven floor of Lewisian Gneiss on which the Torridonian rocks rest. These strata, which occupy about half of the region west of the Moine thrust, consist mainly of a great series of false-bedded grits, or arkoses, with some finer sandstones and thin shales. In the largest area of these rocks, running from Loch Broom southwards to the head of Loch Maree, they generally dip eastwards, but near the northern end, where the breadth is greatest, they dip north-west in one locality, and thus give rise to a geological basin composing the hill of Sàil Mhòr. Along the western margin of this tract the members of this formation rest on the Lewisian rocks with a striking unconformity, which is further indicated by the presence of various Torridonian outliers lying on the Lewisian Gneiss in the vicinity of Little Gruinard, near the northern margin of the map, and farther south at and near the hill called A' Mhaighdean.

Another Torridonian tract, west of Little Gruinard, extends in a nearly southerly direction through part of one-inch map 91 to Loch Ewe and the foot of Loch Maree, and is of considerable interest, as it is the only area in this map which contains the highest group (Aultbea) of the Torridon Sandstone. The strata belonging to this subdivision are found on the north-west or downthrow side of a large fault which strikes S.S.W. from the village of First Coast, and on their north-west side they are bounded by another nearly parallel dislocation,* which also throws down in the same direction, and brings a patch of Mesozoic rocks into the extreme north-west corner of the map. Between these two lines of fracture, and for some distance south-east of the First Coast fault, the dip is often towards the north-west.

Another large parallel fault—the Fasagh fault—crosses the Torridonian and other rocks near the head of Loch Maree, but throws to E.S.E., in the opposite direction to the two other faults just referred to. The outcrop of this fault appears to be shifted for a distance of three miles towards the north-west, by a powerful dislocation which strikes north-west along Loch Maree.† On the south-west side of the Loch Maree fault, Torridonian strata extend along the side of the loch for nine miles to the western margin of the map, excepting a space of half a mile a little north-west of Rhu Noa, where they are covered unconformably by Cambrian quartzite. On this side of the loch they form a much larger area than any other rock. The Lewisian Gneiss emerges, however, from beneath them in a few places, chiefly near the west margin.

---

* These two faults are described in Chapter X.

† This fault is described in Chapter X.

The Torridonian strata which have been affected by the great post-Cambrian movements do not form large masses, but they occur at intervals along the line of complication. The largest forms an outlier on the hill called Meall a' Ghiubhais, about two miles west of the head of Loch Maree. The thrust-plane beneath the displaced materials can be traced in an almost circular crop round the mountain.

The most striking features in the lithological character of the unthrust Torridonian beds are their unaltered condition and the freshness of many of the clastic grains of felspar. Secondary enlargement of the quartz grains, and the development of minute scales of mica in the felspar, are the only important changes that have affected the original constituents. The great bulk of the formation consists of very false-bedded, rather coarse felspathic sandstones (arkoses) with occasional intercalations of finer sandstone and micaceous sandy shale. Coarse angular breccias, chiefly made up of pieces of Lewisian rocks like those exposed in the vicinity, are common at the local base, but perhaps particularly so where this base occurs below a certain stratigraphical horizon, that is the top of the lowest or Diabaig group to be described in the sequel. Above this horizon bands with well-rounded pebbles are frequent, but the pebbles are to a large extent composed of vein-quartz and of other rocks, such as grit, quartzite, chert, jasper, felsite, and quartz-porphyry,* which are quite unknown in the Lewisian Gneiss, and have doubtless been derived from some other pre-Torridonian formation, not as yet recognised in the North-West Highlands, which intervened between the Lewisian Gneiss and the Torridon Sandstone. In the sandstones which make up the bulk of the formation the prevalent felspar is stated by Dr. Teall to be microcline—a felspar which seems uncommon in the Lewisian Gneiss except in the area between Cape Wrath and Loch Laxford, where granite-gneisses and pegmatites are largely developed. Clastic grains of quartz are abundant in all except the finest argillaceous deposits. The larger grains are well rounded, but the smaller, less than .1 mm. in length, are angular. The quartz is often rather cloudy and opalescent, but Dr. Teall has ascertained that the minute hair-like inclusions so characteristic of the blue quartz of the Lewisian pyroxene-gneisses are very rare.

From the nature of the Torridonian rocks it may be inferred that they were accumulated rapidly in an area subject to violent currents and the influx of floods. The remarkable freshness of the felspars seems to indicate that decomposition due to chemical action advanced slowly in comparison to denudation, and from this again we may perhaps infer that the climate was cold or arid.

With the exception of the basal breccias the rocks in the bottom group of the formation, and also those in the top group, are somewhat fine in grain, and include a considerable proportion of sandy shales. But the shales are occasionally rain-pitted and sun-cracked, and cannot therefore have been deposited in deep water.

---

* Some of these pebbles will be further described in the sequel.

The following list shows the three Torridonian groups in this one-inch map. The highest group is placed at the top:—

3. Aultbea Group.—Well-bedded hard brown sandstones with beds of micaceous shale and mudstone. Sometimes ripple-marked and sun-cracked. Occasional bands of black shale.
2. Applecross Group.—Purplish-red or chocolate false-bedded sandstones or arkoses. Layers with pebbles, consisting of vein-quartz, quartzite, felsite, etc., ranging up to 2 or 3 ins. in length. Occasional thin bands of finer sandstone. Where these rocks abut unconformably against steep slopes of Lewisian Gneiss they are liable to pass into coarse breccias formed out of the gneiss, which closely resemble those found in corresponding situations in the lowest group.
1. Diabaig Group.—Hard, fine-grained sandstones, weathering with a red or foxy tint, form most of the top beds, but these are mixed with red mudstones, and greenish and dark-grey sandy shales. At the base are conglomerates or breccias, often epidotic, made of pieces of the Lewisian rocks.

It should be stated that these groups were not established until after part of the district was already surveyed, and, therefore, they are not always differentiated on the map.

We shall now proceed to describe these groups in more detail, beginning with the oldest.

THE DIABAIG GROUP.

The basal conglomerates are often of an epidotic character, and this may be attributed to the denudation of old epidotic surfaces of Lewisian Gneiss. The pre-Torridon surface of this gneiss is frequently seen to be traversed by strings of epidote, as in the sides of Beinn Làir, to be shortly described. The felspathic folia are also often more or less converted into epidosite, so that there is no difficulty in understanding how clastic grains of epidote may form part of the detritus that was first derived from such surfaces by denuding agents.

Four small outliers of the Diabaig group occur near Little Gruinard. The two situated south and east of this place are composed of coarse conglomerate, made up of pieces of gneiss, and dipping north-west. A still smaller outlier is found two miles and a quarter S.S.W. of Little Gruinard.

Not far from these outliers comes a rather long but narrow strip of Diabaig beds on the east side of the large N.N.E. fault near First Coast. The general dip in this strip is north-west at angles of about 20°, and the breadth at right angles to the strike is sometimes a mile, so that the thickness represented may be as much as 1700 ft. The basal beds are evenly-bedded red sandstones which contain large, well-rounded pebbles of white quartzite.

About eight miles east of the north-west corner of the map the shores west of Badbea show red and grey ripple-marked flags which seem to abut against a knob of gneiss.

Farther south, between Lochan Gaineamhaich and Loch na Sheallag, the greater part of the basal group consists of sandstones of a rather bright-red colour. In places, however, below or alternating with these bright-red beds, coarse pebbly sandstones are seen. All these strata dip gently eastward under the coarse grits or arkoses of An Teallach, which are placed in the Applecross group.

On the south side of Loch na Sheallag a series of hard bright-red flaggy sandstones, without pebbles, separates the basal shales from the overlying arkoses. Below these flaggy red beds black shales make their appearance, followed by blue, black, and ferruginous greywacke, and sandy seams in shale, the whole succession having a thickness probably of about 250 ft. A fine section has been laid bare due north of Beinn Dearg Bheag, where almost 40 ft. of black shale can be seen. These shales are full of black streaks and blotches which are strongly suggestive of a possibility of discovering fossils, but up to the present they have yielded none.

The Torridonian outlier on A' Mhaighdean (Fig. 3, p. 57) is of interest, because the most abundant pebbles therein are not composed of siliceous gneiss like the adjacent Lewisian rock, but of hornblende-schist of the Beinn Làir type. The pieces are often 5 or 6 ins. long, and no schist like them is now known *in situ* within a mile and a half. About half a mile north-west of the hilltop the hornblende-schist pebbles are often above an inch in length, and indicate by the direction of their inclination that they have probably come from the south-west. The breccia bands on the north side of Fuar Loch Mòr also contain pebbles, 1 or 2 ins. long, of the Beinn Làir type of hornblende-schist, and are still farther from the nearest exposure of such schist.

On the north-west side of Slioch, an outlier, consisting mainly of coarse breccia, extends from near the foot of Loch Garbhaig far up the high ground to the north-west. As it ascends it divides into irregular arms which show well the steepness of the surface on which the breccia was deposited. Four other small outliers of similar rock still higher up indicate how the hornblende-schist has here been encased in Torridonian sediments. Again, the patch of coarse breccia which rests on the steep hillside of hornblende-schist on the north side of Loch Garbhaig, half a mile east of the outlet, shows clearly that its different beds have been deposited almost horizontally against a steep face of the schist. Where no breccia is now left, the planes of the hornblende-schist are frequently stained with hæmatite, and are streaked with thin veins of hæmatite, while the quartz veins are reddened, and abundant epidotic strings have been developed, the epidote being sometimes in distinct crystals embedded in quartz veins. Examples of these phenomena may be found to the west, south-west and east of the top of Beinn Làir, in one case at a height of more than 2500 ft.

On the south side of Loch Maree the Diabaig beds are well exposed in the section cut by the River Lungard at Talladale (see Fig. 12 in the Memoir on "The Geological Structure of the North-West Highlands"). The top beds, about 100 ft. thick, consist of hard compact brick-red grits, with no pebbles, and below these comes a series of black and grey shales, greywackes, reddish grits and shales, amounting together to about 250 ft. Another fine section of black grits and dark and grey shales is also visible in the wooded glen a mile S.S.E. of Talladale.

In the outlier of thrust Torridon Sandstone that forms most of Meall a' Ghiubhais—the hill two miles west of the head of Loch Maree—the strata are not much deformed save near the thrust-planes. In such positions the grits are sometimes rendered somewhat schistose, and the shales are slightly cleaved.

THE APPLECROSS GROUP.

The sandstones and arkoses of this group are coarser in grain than the top sandstones of the Diabaig group, and weather with different colours, purplish or brownish-red instead of foxy. The former colours seem due, partly to the original colour of the fresh grains of felspar, partly to the red staining of the more altered felspars or fragments of felsite, and partly to thin pellicles of iron oxide which coat the individual clastic grains. These pellicles may be regarded as the result of subaerial decomposition of the old land surface from which the materials were derived. In many of the beds, grains of felspar are as abundant as quartz, and include a considerable proportion of microcline and microcline-microperthite, which are in a very fresh condition.

False-bedding is extremely prevalent, so much so that the true dip is often difficult to ascertain, excepting by the help of intercalated beds of finer sandstone. The minor laminæ in the false-bedded layers are often curved into a vertical or even reversed position.* They differ in grain as well as colour, and do not, therefore, represent lines of staining merely. Their upper ends are often cut off abruptly by the even base of the overlying bed without the least indication of shearing or slickensides. Such curved and reversed laminæ are often seen many miles away from the post-Cambrian complications, and it is certain that they have not been affected by them. The phenomena must be due to some cause which was operative again and again in Torridonian times. In many cases it affected a bed before it was covered up by the overlying layer, and probably, therefore, before it was in a completely consolidated condition.

Intercalated with this series of arkoses are a great number of thin seams, often only an inch or two thick, which contain well-rounded pebbles, as much as 2 or 3 ins. in length, of vein-quartz, quartzite, felsite, quartz-felsite, and chert or jasper. When the pebbly beds decay, the pebbles are left behind on flattish rock surfaces, while the fine sand is blown or washed away. The pebbles of vein-quartz are white and identical in character with that which occurs so commonly in disturbed regions. The quartzite pebbles are either light-grey, pale-red or liver-coloured. They are not sheared, but represent sandstones which have been indurated by the deposition of secondary silica on the original grains.

The felsites are chiefly of a purplish colour, and are stated by Dr. Teall to be identical in all respects with the felsites of the Uriconian Series of Shropshire. No organic structures have been discovered in the cherts. It is difficult to draw a line between the cherts and jaspers, and it is quite possible that some of the latter may represent silicified felsites. A collection of pebbles made by Dr. Horne in Srath Lungard, south of the Lochmaree Hotel, contained different pebbles in the proportions indicated below:—

---

* This type of false-bedding is noticed by Sir A. Geikie, who gave a sketch of an example of it in his "Text-Book of Geology" (1882), p. 479. The same type is occasionally observed in the Carboniferous sandstones.

Vein-quartz	50	per cent.
Quartzite	20	,,
Chert and Jasper	16	,,
Grit	8	,,
Felsite and Felspar-porphyry	6	,,
	100	,,

The proportions in different localities vary, however, considerably.

The pre-Torridonian surface of the Lewisian Gneiss east and south-east of Slioch was in places of a very steep, rugged character, as already indicated, and where the Applecross rocks abut against it they often pass into coarse breccias, which do not, however, extend far, perhaps rarely more than 80 or 100 yds. from the old surface (see Fig. 11 in the Memoir on "The Geological Structure of the North-West Highlands"). At the north end of the inlier pieces of breccia are seen sticking to the cliffs of hornblende-schist, and sandstone veins fill up thin cracks in the schist. The basal Torridonian beds near the mouth of Abhuinn an Fhasaigh, also, consist of coarse breccias containing pieces of Lewisian rocks like those found in the immediate vicinity.

The disintegration of the sandstones in exposed positions sometimes gives rise to effects that are usually thought in this country to be confined to our coasts. On the high plateau between the peaks of An Teallach and Mac' us Màthair, to the north, the sandstone is decomposed to great depths, and the loose sand blown about by the wind forms dunes comparable to those ordinarily seen on the seashore. Similar phenomena occur on the top of Slioch.

Between Loch na Sheallag and the summit of An Teallach the thickness of the beds of the Applecross group still preserved is probably 4000 ft. or more, but no remains of the highest or Aultbea group exist, and it is impossible to say what thickness of Applecross beds has been removed by denudation. It is to this great thickness of beds of almost uniform character that we owe the characteristic mountain features already described.

The extensive area occupied by the Applecross group on the south-west side of Loch Maree is divisible into two parts by an important fault, striking N.N.E. and with a large downthrow to the east, which is supposed to be the continuation of the Fasagh N.N.E. fracture, its outcrop having been shifted for three miles by the Loch Maree wrench fault. On the east side of this dislocation the rocks are much broken by parallel joints and generally dip eastwards, very steeply for 200 yds. or more next the fault, but more gently farther off. On the west side the beds are rolling about at gentle angles and are often nearly flat.

Arkoses belonging to this group, sometimes much deformed, occur at intervals along the line of complication between Loch Broom and Kinlochewe.

THE AULTBEA GROUP.

In the north-west corner of the map the beds referred to this group are found on the west or downthrow side of the N.N.E. fault which comes to the shore at First Coast. These beds are, however, in most places so much jointed, shattered and veined with quartz that they cannot always be distinguished from the lower portions of the Torridonian Series.

Just along the course of the fault on the south side of Beinn Dearg Bad Chailleach, a wedge of limestone, about 9 ins. thick, is seen in one place, and also a dirty-white or grey siliceous band. These are probably parts of the Cambrian Series crushed down in the fault. W. G., C. T. C., B. N. P., E. G.

CHAPTER V.

CAMBRIAN FORMATION.

In the area to the west of the post-Cambrian displacements, the Cambrian strata, as already indicated, form a narrow belt traceable from the northern margin of the map to the shores of Loch Maree and the Kinlochewe Forest. Everywhere along this belt they rest unconformably on the Torridon Sandstone. In the central part of the belt near Loch an Nid the discordance between the two formations is clearly seen, bed after bed of the red sandstones being transgressed by the basal quartzites. South of Lochan Fada, however, where a strike section is exposed for two miles, the unconformability is not very apparent, though the boundary between the two is distinctly traceable.

The quartzites have the largest development, as they range from 500 ft. to 600 ft. in thickness. The five sub-zones of the Pipe Rock,* based on the peculiar forms of the pipes due to burrowing annelides, have been identified in the area under description. But the most important members of the series are the Fucoid Beds and Serpulite Grit, owing to the occurrence in them of trilobite-bearing bands, which, prove that they are of Lower Cambrian age. J. H.

AREA FROM LOCH LAGAIDH TO STRATH NA SHEALLAG.

Between the northern edge of the map and Strath na Sheallag the subdivisions of the Cambrian Quartzite are well exposed in many places, but the higher Cambrian rocks, namely, Fucoid Beds, Serpulite Grit and Durness Limestone, are often obscured.

Beginning at the north end, we find in the area about Loch Lagaidh that a good deal of the quartzite is drift-covered, but the base line is clearly traceable, and in several places west and north-west of this loch the characteristic conglomerate—which forms the lowest part of the quartzite—is clearly exposed. It is a *remanié* deposit, composed mainly of pebbles derived from the underlying Torridon Sandstone, and its junction with that formation is visible a little to the south of the most easterly of the two small lochs there. The boundary between the False-bedded Quartzite and the Pipe Rock is not always quite clear, as some of the latter rock is occasionally false-bedded. The trumpet-pipe division (sub-zone iii.) is well exposed along the north-western side of Loch Lagaidh, and loose blocks of the beds included in sub-zone iv. occur nearly in place farther south.

The dip of all these rocks is very steadily to the east-south-east at angles between 15° and 18°.

---

* The characteristics of these five sub-zones are described in the Memoir on "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Surv.* (1907), pp. 372, 373.

The quartzose conglomerate at the base of the quartzite, several feet in thickness, may be seen on the north side of the small stream half a mile south-west of Loch Lagaidh, and again on the south side of the next stream, Allt na h-Ighine, which comes from Loch Lagaidh. In this stream there is a good exposure of the greater part of the quartzite. A fault running along the gorge throws down about 30 ft. on the north side. The next stream on the south, called Allt a' Char, which comes from Loch a' Chàrnain Bhàin, affords the most complete section of the Cambrian rocks, as it exposes not only the subdivisions of the quartzite, but the Fucoid Beds and Serpulite Grit also, and a small portion of the Durness Limestone. Some thin grey shaly bands occur in the section of the basal quartzite. A scar south of the burn gives a measured thickness of 240 ft. of Basal Quartzite, and 100 ft. of Pipe Rock up to the trumpet zone (sub-zone iii.). Probably the total thickness of the False-bedded Quartzite is 300 ft. or more, and that of the Pipe Rock quite 250 ft. The brown, impure, or dolomitic limestone of the Fucoid Beds and the blocky Serpulite Grit succeed in regular order, and above the latter appears some grey limestone. The section on the south side of the burn is the following :—

Grey limestone, perhaps . . .	20 ft.
Serpulite Grit	12–15 ft.
Grey, flaggy, rather siliceous Fucoid Beds .	a few ft.

Above the limestone appears the thrust Torridon Sandstone elsewhere described. It must also be borne in mind that there are thrusts and disturbances in the Fucoid Beds and Serpulite Grit north of the stream. These latter divisions appear again in the next stream to the south, on the north side of Creag Chorcurach, but no limestone is visible except in Allt à Char. Southward from Creag Chorcurach for some distance the quartzite is only occasionally exposed till we reach the Strath Beg River, where there is a good exposure of the middle portion of the rock, at and below the bridge. To the southward both divisions of the quartzite are clearly exposed for nearly four miles, the Pipe Rock spreading out over a dip slope extremely glaciated, while the Basal Quartzite generally forms a fine series of crags.

Several small faults which mostly run in an east-north-east direction cross the outcrop of the quartzite. The most northerly of these, which is the longest, exhibits for a long distance a fine cliff-face on the south, which is probably the upthrow side. The one west of Loch Coire Chaorachain, with a downthrow to the north, appears to be much the largest and shifts considerably the Moine thrust. The general dip of the rocks both in direction and in amount is much the same here as about Loch Lagaidh. The Fucoid Beds and Serpulite Grit crop out in the stream, Allt Gleann Chaorachain, and appear in places to the south, but the latter rock is soon overlapped by the Moine thrust and does not appear at all for a long distance north of Strath na Sheallag.

The outliers of quartzite that are found on the three spurs of An Teallach, at a height of over 3000 ft., and considerably to the west of the main outcrop, prove that the Cambrian rocks once extended a long way farther west than they do now. The most northerly of these outliers, which is also the smallest—that on Glas Mheall Mòr—contains only a small portion of the lower beds of the Basal Quartzite.

The outcrop is about 150 yds. in length, and much of it is loose rock, but at the west end 5 or 6 ft. of the pebbly base of the quartzite may be seen *in situ*. The next outlier, a mile farther south, on the hill called Glas Mheall Liath, is much more considerable. Though the base is almost everywhere obscured by tumbled rock, there is clear evidence that in this outlier there is not only the whole of the Basal Quartzite but a small portion of the Pipe Rock also. At the west end several feet of the pebbly base are visible, and the rock is exposed in places along the ridge eastwards to where the Pipe Rock occurs. Viewed from the valley to the eastward, this outlier appears to be a conical hill of quartzite, and as such it has been sketched and described, but it is only the end of a ridge. The numerous angular blocks of white quartzite which encumber the steep slopes far below the actual outcrop of the rock considerably increase the deceptive appearance. The most southerly of the three outliers—that which forms the top of Sàil Liath—is much the largest, but it is principally composed of the Basal Quartzite, only the lower part of the Pipe Rock appearing—probably no greater in amount that what appears on Glas Mheall Liath. At a few places near the west end of the outlier and in numerous localities along the north-eastern side there are clear outcrops of the False-bedded Quartzite, which is seen to have the same dip (15° to 18°), both in direction and amount, as the main mass of the same rock to the eastward. All the three outliers are alike in this respect. W. G.

AREA FROM STRATH NA SHEALLAG TO KINLOCHEWE FOREST.

Throughout this tract the lower and upper divisions of the quartzites present their usual characters and retain their normal thickness. The former westward extension of the Cambrian strata is proved by an outlier of the basal quartzites on the crest of Beinn a' Chlaidheimh, at a height of 2750 ft. and about a mile distant from the main outcrop of the lower division. Excellent sections of the whole arenaceous series are laid bare on the dip slopes of Sgùrr Bàn and Mullach Coire Mhic Fhearchair, where the beds are inclined to the E.S.E. at angles varying from 16° to 30°. At one locality, on the crest of the ridge north of the top of Sgùrr Bàn, vertical worm-casts were detected in one of the bands of False-bedded Quartzite, this being the only recorded instance of the presence of organic life in the lower division of the quartzites in the North-West Highlands.

On the southern declivity of Mullach Coire Mhic Fhearchair the outcrops of the quartzites are shifted more than a mile to the south-west by the Fasagh fault. On the downthrow side of this fracture they appear on the shore of Lochan Fada and form a prominent escarpment, on the east side of Gleann Bianasdail, which can be followed southwards to the Kinlochewe valley. Here again the outcrops of the arenaceous series are abruptly truncated by the Loch Maree fault traversing that valley, and have been carried about two miles to the north-west beyond Rhu Noa. From that point they have been traced round the western face of Meall a' Ghiubhais, the beds having an E.S.E. inclination at angles varying from 15° to 22°.

Special interest attaches to the exposures of Fucoid Beds and Serpulite Grit, both being traceable, in the unthrust area, more or less continuously across the Sheet. In the sequel it will be shown that in certain places along the line of outcrop, the first powerful thrust occurs on the horizon of the Fucoid Beds.

The locality, where the trilobite-bearing bands in the Fucoid Beds were first observed, and where portions of *Olenellus* were first found by A. Macconochie, occurs in Allt Righ Iain, a small stream on the east side of the Loch an Nid valley, and about three miles E.S.E. of Loch na Sheallag. At the point where the burn is crossed by the hill-road between Dundonnell and Achneigie, the upper portion of the Fucoid Beds is exposed, containing two prominent bands of dark-blue shale, intercalated in the normal dolomitic beds of the zone. The upper band lies about 3 ft. and the lower one about 9 ft. from the top of the Fucoid Beds. The fragments of *Olenellus* were found in the lower band, the best specimens being confined to a seam less than an inch thick. Some of these dark-blue shales are slightly calcareous, and are traversed by small worm-casts. The upper limit of the Fucoid Beds in this section is well defined, the base of the *Salterella* (Serpulite) Grit forming a small cascade over which the stream leaps on to the softer beds below.

The *Olenellus* shales with their characteristic fossils, and the dolomitic bands associated with them yielding *Hyolithes* sp., are also exposed north of Allt Righ Iain in small streams that drain southwards into the Loch an Nid River above Achneigie.

Farther south, near Loch an Nid, fragments of trilobites were found in thin shales intercalated with the Serpulite Grit. About 450 yds. to the north of that lake the following vertical section is exposed in an escarpment cut by a streamlet on the east side of the valley, beneath a mass of disrupted Lewisian Gneiss:—

		Ft.	In.
Zone of *Salterella* Grit	Grey quartzose grit	18	0
	Flaggy grits with intercalated shales . .	7	0
	Grey shales	1	0
	Dark-blue shales containing *Olenellus* . .	0	8
	Grey grit	2	0
	Dark-grey shales	1	6
	Grey quartzite	7	3
Top of Fucoid Beds	Brown dolomitic bands with bands of dark shales	5	3

The dark-blue shales intercalated with these grits and quartzites have yielded a carapace of *Olenellus Lapworthi* and other fragments of this form. These shales are underlain by grey grits and quartzites forming the lower portion of the Serpulite Grit. When traced southward along the hill-slope the upper and lower ledges of quartzose grit coalesce and form a prominent escarpment overlying the Fucoid Beds.

At certain localities along the base of the Loch an Nid crag, beneath the disrupted Lewisian Gneiss and Torridon Sandstone, the undisturbed Serpulite Grit is overlain in normal sequence by the basal beds of the Durness dolomite charged with *Salterella*.

The Fucoid Beds and Serpulite Grit are exposed round the margin of the slice of disrupted gneiss overlying the Kinlochewe thrust-plane on Mullach Coire Mhic Fhearchair, and again on the escarpment on the east side of Gleann Bianasdail.

The best section of the trilobite-bearing bands of the Fucoid Beds occurs to the south of Loch Maree, about a mile from the shore of that lake. The zone is laid bare in a small stream that issues from Loch Bhanabhaig and flows down the northern slope of Meall a' Ghiubhais (2282 ft.), a hill formed of an outlying mass of thrust Torridon Sandstone. Though not far beneath the plane of the Kinlochewe thrust, the beds are not deformed nor are the fossils distorted. The fossiliferous subdivisions as worked out by A. Macconochie are given below in descending order:—

	Ft.	In.
SERPULITE GRIT		
7. Blue clayey and sandy shale full of small vertical worm-casts, yielding occasional fragments of *Olenellus gigas* and *Olenellus Lapworthi*	18	0
6. Shale with well-preserved brachiopods (*Acrothele subsidua*)	0	9
5. Dark flaggy or platy shale, with fragments of *Olenellus* at base	2	10
4. Ferruginous yellow dolomitic band, with conchoidal fracture	0	7
3. Pisolitic ironstone with remains of trilobites and echinoderms	0	2
2. Hard ferruginous dolomitic band, the bottom film crowded with carapaces of *Olenellus*	0	3½
1. Soft, jointed, cleaved, clayey shale. The topmost seams yield occasional complete specimens of *Olenellus* and fine examples of *Olenelloides armatus*; the lowest two inches are crowded with disjointed and broken segments of *Olenellus*. This band of shale is termed the *Olenellus* layer	0	11

The dolomitic Fucoid Beds are exposed in the stream farther down.

The distribution of the Cambrian strata in the displaced masses between Strath na Sheallag and the Kinlochewe Forest is extremely irregular. In the Dundonnell Forest and southward to the Heights of Kinlochewe they appear as thin lenticles traceable for no great distance. Beyond that locality, in the lower part of Glen Bruachaig, folded and thrust quartzites, Fucoid Beds and Serpulite Grit, rise from underneath the mass of Lewisian Gneiss overlying the Kinlochewe thrust-plane. The cleaved Fucoid Beds, visible in the channel and on the banks of Abhuinn Bruachaig, contain the pisolitic ironstone and the soft shale beneath, from which carapaces of *Olenellus Lapworthi* and *Hyolithes* have been obtained.

Again, among the materials carried westward by the Kinlochewe thrust there is conclusive evidence of the double unconformability of the basal quartzite on the Torridon Sandstone and Lewisian Gneiss.

South from the head of Loch Maree and the Kinlochewe River, the Cambrian strata, repeated by numerous folds and thrusts, cover a broad belt of ground to the east of Meall a' Ghiubhais.

B. N. P., J. H.

CHAPTER VI.

POST-CAMBRIAN MOVEMENTS.

In the area between Loch Broom and Loch an Nid, as already indicated, the belt of complication is comparatively narrow. Indeed, in some localities, as, for instance, in Strath Beg, the Eastern Schists overlap all underlying thrust materials and rest directly on the undisturbed Cambrian strata. The section of special interest in this northern portion occurs on the plateau east of Dundonnell Lodge, where the Moine Schists and Moine thrust-plane, together with the underlying displaced materials, have all been thrown into an anticlinal fold, while the Cambrian rocks beneath the Ben More thrust-plane have not been affected by that movement.

In the southern part of the map, on either side of the Kinlochewe valley, the belt of complication is several miles in width. Remarkable evidence is there obtained (1) of the reduplication of the strata over miles of ground by inverted folds and minor reversed faults in advance of the powerful lines of disruption; (2) of the folding and faulting of the great thrust-planes; and (3) of the formation of a large outlier of displaced materials overlying the Kinlochewe thrust-plane on Meall a' Ghiubhais, near Kinlochewe. In the following description, the Kinlochewe thrust is regarded as the equivalent of the Ben More thrust in Assynt. J. H.

AREA FROM LOCH BROOM TO STRATH NA SHEALLAG.

On the west side of Loch Broom the area occupied by thrust rocks stretches for nearly a mile along the shore (Sheets 101 and 92), and the ground rises southwards so as to reach the level of 1250 ft. above the sea. It falls again gradually to the valley of Strath Beg, where it is only 200 ft. Along this part of the belt of complication there is only one place where the width is considerable, namely, in the striking anticline just referred to east of Dundonnell Lodge. South of Strath Beg the thrust area is very limited in breadth. The ground, however, rises to a height of 1500 ft., the highest point it reaches in this district.

We shall begin the description of the line of complication at the north end, where the Moine thrust may be observed on the west side of Loch Broom, south of Blarnalevoch. The displaced, flaggy, grey, quartzo-micaceous schists here overlie much altered Torridon Sandstone, and the plane of separation dips to the east-south-east at an angle of 10°. The outcrop of the thrust-plane trends at first westwards and then north-west, till it attains a height of more than 1000 ft. at a distance of nearly a mile and a half from the loch, where it forms a good feature. It is clear that the plane has a gentle slope to the east-south-east of about 10°, and for a long way coincides with the slope of the ground. About three-quarters of a mile north from Loch Lagaidh the line of thrust unmistakably crosses the strike of the schists, and here the direction of outcrop changes to the south-south-west.

In this area west of Loch Broom there is only one other main thrust, which is probably continuous with that which has brought westwards the Lewisian Gneiss with patches of Torridon Sandstone, east of Corry Point, on the north-east side of Loch Broom (Sheet 101). It appears for a considerable distance to keep along an even surface near the top of the Serpulite Grit, and it enters this sheet one mile north-north-east of Loch Lagaidh, along the eastern side of which loch it passes. Between these two main thrusts the ground west of Loch Broom is occupied mainly by deformed Lewisian Gneiss, on which repose unconformably many patches of crushed Torridon Sandstone, whose boundaries are often obscured by glacial drift. Sections of the sandstone may be noticed along the Blarnalevoch shore. It is often crushed or shattered ; is generally of a reddish colour, but is sometimes green, and usually veined with many interlacing quartz strings. It varies much in coarseness of grain, and the bedding is often obscure. The largest mass of it is about a mile from the loch.

The grey hornblendic gneiss, mainly of an acid character, is also a good deal covered by drift in the lower ground. In it there are a good many large irregular masses of basic composition, some of which may possibly be deformed dykes, but probably most of them form part of the Fundamental Complex. One of the largest of these is mainly within the enclosed ground of Blarnalevoch; others may be seen on the high ground north-north-east of Loch Lagaidh. There is little trace of any foliation to be observed in these basic masses or in the acid gneiss with which they are associated.

When we follow the thrust area southward, we find that the gneiss ends not far to the south of Loch Lagaidh, and for some distance beyond that lake Torridon Sandstone only is found in a band about 80 yds. wide. The rock is much deformed in character, and generally is much less coarse than the arkose division of unthrust Torridon Sandstone which forms the high hills to the westwards. Soon the width of the complicated belt increases, and again we find in it Lewisian Gneiss; but this latter rock occurs only for a distance of 200 yds., and is adjacent to the Moine thrust. Farther south for about half a mile the displaced Torridon Sandstone forms a strip 170 yds. in width, and apparently it overlies the Serpulite Grit. But near the next stream there must be one or more minor thrusts to the westward, for we find the Serpulite Grit and part of the Fucoid Beds repeated, and the dip of the latter zone much increased. This may be seen in the principal stream here called Allt a' Char, which flows from Loch a' Chàrnain Bhàin. The Serpulite Grit appears in this burn to the eastward, and above it, on the south side, a band of grey limestone about 20 ft. thick apparently. Over the limestone is thrust the Torridon Sandstone, sections of which are found in the burn for a distance of 200 yds. higher up, followed by the crystalline, flaggy Moine Schists dipping at a low angle to the north-east.

We now approach an area of remarkable structure, for the displaced rocks have been bent or contorted in a wonderful manner, while the main mass of the Cambrian and Torridonian strata in the undisturbed region to the west have their usual inclination. The folded tract stretches in an east-north-east direction for more than a mile, with a breadth of a quarter of a mile, and it lies between Allt a' Char and Creag Chorcurach. The structure is that of a sharp anticline, the axis of which is in the direction of the length of the area, and the disturbance affects not only the thrust rocks but extends eastward for many miles into the region of the Moine Schists. The map shows that the outcrop of the Moine thrust-plane takes a sharp bend eastward on the north side of the anticline, and returns on the south side to resume its usual direction. A large part of the complication is covered by drift and peat, but the rocks exposed give a clue to the general structure (Fig. 2).

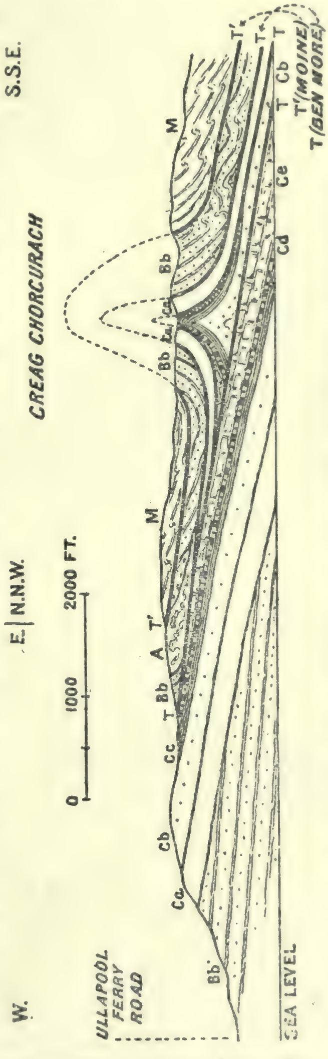


Fig. 2.—Section across Anticline near Creag Chorcurach, one mile east from Dundonnell Lodge, Little Loch Broom.

A. Lewisian Gneiss. Bb. Applecross Group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe Rock. Cc. Fucoid Beds. Cd. Serpulite Grit. Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine Thrust.

In the western part of the central line of the anticline there is an almost continuous outcrop of the Fucoid Beds (Cc in Fig. 2) for a distance of 650 yds. They are everywhere vertical with a general strike to east-north-east, and though necessarily repeated by the sharp fold, they probably represent the whole thickness, as the width of outcrop in some places is nearly 150 ft. They disappear under thick peat at the eastern end of the slight ridge which they form, and it is impossible to say how much farther they may extend in that direction. Their western outcrop is also lost about 150 yds. to the north-east of the ordnance station (1193 ft.) on Creag Chorcurach. Here a small exposure of Serpulite Grit occurs on the south side of them, so that it seems probable from this and other indications that this rock (Cd, Fig. 2) stretches in a vertical strip on either side of the ridge formed by the Fucoid Beds. In one place, about 200 yds. from the eastern end, there is found, some way to the north-west of the Fucoid ridge, an outcrop of quartzite (Ca, Fig. 2), and it appears probable that there is a thrust strip of this rock on both sides of the anticline, though little can be seen on the south side for peat and drift.

It is quite certain, however, that thrust Torridon Sandstone (Bb) occurs on both sides of the anticline, for we find it in several places; and it may fairly be inferred that there is a continuous strip of this rock all round the sharp curve, adjoining the Moine Schists, and connected with the band that has been traced from Loch Lagaidh. From the position of this sandstone, with respect to the quartzite on the north side of the anticline, it is evident that the older rock is superimposed on the quartzite by a thrust, and the latter in like manner has been brought over the Serpulite Grit. That these rocks and the Moine Schists also have moved westwards on a thrust-plane which is not arched like the others, is evident from the fact that the main masses of quartzite and Torridon Sandstone in the undisturbed area to the west show no trace of the anticline which exists in the thrust rocks (see Fig. 2). The Torridon Sandstone on the south side of the anticlinal fold is a light-coloured siliceous grit which is sometimes a conglomerate, but rendered so schistose as at first sight to be barely recognisable. It is much veined with quartz, like the same material on the north side of the arch. As we go south-eastward the rock is still more altered, and, having the same dip and strike as the flaggy Moine Schists, it becomes exceedingly difficult to determine where the line separating them should be. This difficulty does not occur on the north side of the area in question, for we find to the north of the recognisable Torridon Sandstone, and at no great distance from it, a laminated very siliceous grey rock, much contorted, in a ridge along an east-and-west strike, which is undoubtedly a portion of the Moine Series. But on the south side, to the east of the ordnance station on Creag Chorcurach, there occur here and there bands of a coarse, gritty schist or crushed gneiss alternating with finer Moine-like bands, and whether the whole of this material is altered Torridon Sandstone or that rock alternating with the Moine Schist it is impossible to determine. It should therefore be understood that the line here drawn on the map separating the schistose Torridon Sandstone from the Moine Series is purely conventional. Several specimens from this district have been microscopically examined, but the rocks are so much crushed that no definite opinion can be formed of them. Some are more probably crushed grits, while others more resemble crushed gneisses or pegmatites.

To the south of the small burn immediately north of Creag Chorcurach, the Serpulite Grit and the Fucoid Beds soon disappear, and the main thrust occurs just above the Pipe Rock, and probably there are minor reversed faults in that zone. Under Creag Chorcurach is a thick mass of flaggy siliceous mylonite apparently shattered by normal faults. To the south of this crag the Fucoid Beds and Serpulite Grit are traceable for some hundreds of yards, and midway along this strip some schistose quartzite appears over the Serpulite Grit. Farther south the undisturbed Pipe Rock is immediately overlain by a thick mass of siliceous mylonite, which forms the lower parts of Creag Mhòr and Creag Bheag to the east of Dundonnell House. Over the mylonite comes the flaggy Moine Schist, but the boundary between the two rocks is not well defined, and, in fact, they appear to pass into each other. It seems probable that the mylonite represents not only crushed and rolled-out members of the Cambrian Series and of the Torridon Sandstone, but also crushed crystalline schists. Deformed Torridon Sandstone perhaps enters more largely into the composition of this mylonite, and there are indications that a considerable portion may consist of rolled-out Lewisian Gneiss.

The belt of complication in Strath Beg is much contracted, and it appears that the Moine thrust has here brought the mylonite and Moine Schists over the undisturbed Cambrian strata. This line of disruption apparently continues just above the Serpulite Grit for a mile to the southward of the river up the east side of Allt Gleann Chaorachain. A large part of the flaggy schistose rock forming the crags of Cadha Buidhe is probably mylonite. The rock is, for the most part, very siliceous and flaggy, and some of it has much the appearance of a deformed grit. There is not much mica on the surfaces of the planes adjacent to the line of thrust, but no good line can be drawn between these rocks which have comparatively little mica and the more micaceous schists to the eastward.

On the watershed west from Loch Coire Chaorachain a thin slice of deformed Torridon Sandstone again appears between the Moine thrust to the east, and the Fucoid Beds in their normal position beneath the Ben More thrust-plane to the west. It is traceable for about 600 yds., till it is cut off at the south end by a fault running in an E.N.E. direction. Farther south, towards Strath na Sheallag, the Moine thrust again overlaps all underlying disrupted rocks, and, for a long distance, the Eastern Schists rest directly on the undisturbed Fucoid Beds. W. G.

AREA FROM STRATH NA SHEALLAG TO KINLOCHEWE FOREST.

In the tract between Strath na Sheallag and Loch an Nid, one point of special interest is the occurrence of the double unconformability of the Cambrian quartzite on the Torridon Sandstone and Lewisian Gneiss in the masses brought westward by the Ben More thrust, to which reference will now be made.

The two powerful displacements (Ben More and Moine) run close to and nearly parallel with each other for about three miles, except at a point about a mile and a half S.S.E. from Achneigie, where the Eastern Schists rest directly on the unthrust Cambrian strata. The positions of these lines of disruption are well defined in the burn sections and on the escarpment on the east side of Amhainn Loch an Nid. For a long distance the materials above the Ben More thrust-plane consist of a thin wedge of Torridon grit not much deformed till the observer approaches Loch an Nid. In that direction, at various localities, the Lewisian Gneiss rises from beneath the Torridonian strata which rest unconformably upon the gneiss. At one point, about 270 yds. south from a turf and stone dyke that crosses the valley, the junction between the two is clearly seen. Beneath the Ben More thrust-plane, the *Salterella* dolomite there rests in normal sequence above the Serpulite Grit and Fucoid Beds. Above the plane, the disrupted gneiss is seen to consist of pink granitoid rock with basic knots. The basal Torridonian conglomerate, probably marking the local base of the Applecross division, is coarse, and contains pebbles varying from seven inches to a foot across.

The largest are composed of pink granitic and basic material like the rocks of the underlying floor, the smaller ones, from half an inch to an inch in diameter, consist of felsite, jasper, quartz, and altered purple quartzite. It is worthy of note that these pebbles are not deformed, nor is the matrix schistose, as is the case with the same conglomerate above the Ben More thrust-plane in the Oykell valley, Assynt. The overlying grits and shales are not schistose; they are merely crushed and veined with quartz.

About 300 yds. south from the locality just described and along the 1250-ft. contour line a small patch of basal quartzite is seen to rest unconformably on the Torridon grits. Farther south, and almost due east of the outlet of Loch an Nid, another unconformable outlier of the quartzite reposes partly on the Torridon Sandstone and partly on the Lewisian Gneiss.

The relations of the strata at Loch an Nid and in the mountainous ground to the west are shown in the section given in Fig. 3. The western part of this section, beyond the belt of complication, illustrates the uneven character of the land-surface on which the Torridonian sediments were laid down. On the western slope of Mullach Coire Mhic Fhearchair these sandstones and grits (Bb), which reach there a thickness of about 2000 ft., can be seen to have been accumulated around and above hills of Lewisian Gneiss that rise to a height of 1000 ft., and are now gradually being uncovered in the progress of denudation. Above this pile of sediment the Cambrian quartzites (Ca) rest unconformably on the eroded edges of the Torridon Sandstone, followed in order by the Pipe Rock (Cb), the Fucoid Beds (Cc), Serpulite Grit (Cd), and a few feet of the basal dolomite (Ce). At this horizon in the Cambrian Series the undisturbed strata are abruptly truncated by the Kinlochewe thrust (T), which has brought westwards a cake of Lewisian basic and acid gneisses traversed by epidiorite dykes (Bg). These rocks (A) rest on the inclined thrust-plane, and form a serrated ridge on the eastern slope of the mountain. Several minor thrusts or reversed faults, not shown in the figure, affect the course of the dykes. On the west side of the Loch an Nid valley, on the dip slope of Sgùrr Bàn, a small patch of gneiss, which has been isolated by denudation from the thrust mass on Mullach Coire Mhic Fhearchair, is named Meallan an Laoigh (the calf hillock). The Fucoid Beds and Serpulite Grit can be traced round this outlier, and the basal dolomite appears on its western side, truncated in like manner by the Kinlochewe thrust (see Fig. 3).

East of Loch an Nid a normal sequence of undisturbed Cambrian rocks is traceable from the Pipe Rock to the basal dolomite, above which, as already indicated, the rest of the Cambrian Series has been displaced by the Kinlochewe thrust. The Lewisian rocks which now supervene are overlain by the Torridon Sandstone (B), with the basal quartzite (Ca) resting unconformably on both. Above these displaced materials, thrust Pipe Rocks, Fucoid Beds, and a thin wedge of Lewisian Gneiss are truncated by the Moine thrust (T′), which has driven westward the granulitic schists of the Moine Series (M).

The belt of Lewisian Gneiss between the Kinlochewe and Moine thrust-planes, which stretches southwards from the eastern slope of

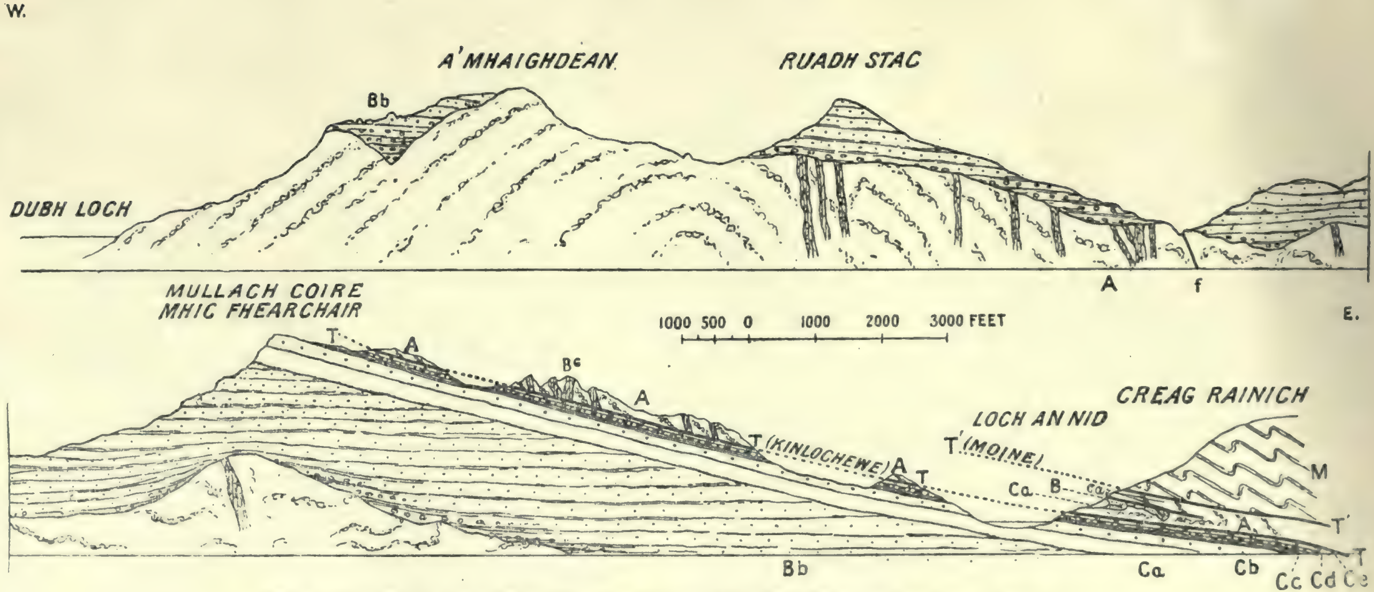


FIG. 3.—Section from A' Mhaighdean by Mullach Coire Mhic Fhearchair to Creag Rainich.

A. Lewisian Gneiss. Bc. Dykes in Gneiss. B. Torridon Sandstone. Bb. Torridonian Breccias. Ca. Basal Quartzite (Cambrian). Cb. Pipe Rock. Cc. Fucoid Beds. Cd. Serpulite Grit. Ce. Limestone. M. Moine Schists. T. Kinlochewe Thrust. T'. Moine Thrust. f. Fault.

Mullach Coire Mhic Fhearchair to the Kinlochewe valley is not much deformed except near the great lines of displacement. The basic dykes preserve their north-westerly trend and their clear intrusive junctions with the gneiss. On the surface of this plateau of disrupted Lewisian rocks small isolated patches of Torridon Sandstone occur, as shown on the map. Thus, about half a mile east of Lochan Fada, the basal breccia is seen to rest unconformably on the old floor, followed by shales, but the strata are here highly contorted and inverted. Farther to the north-east, on the western slope of Beinn Bheag and close to the outcrop of the Moine thrust-plane, the double unconformability of the Cambrian quartzite on the Torridon Sandstone and Lewisian Gneiss is again visible.

The outcrop of the Kinlochewe thrust-plane, which bounds the displaced Lewisian rocks to the west, is shifted for about a mile to the south-west by the Fasagh fault to a point near the outlet of Lochan Fada. It then passes southwards along the escarpment west of Beinn a' Mhùinidh to the Kinlochewe River.

At the Heights of Kinlochewe evidence has been obtained of an intermediate displacement in advance of the Moine thrust, accompanied by marked deformation. A triangular mass of highly-sheared gneiss here displays a narrow infold of Torridon Sandstone and shales (Diabaig group), traceable along the east side of Gleann na Muice for three-quarters of a mile. These sediments have been rendered schistose, an alteration specially apparent in the grits. The deformed gneiss and Torridon Sandstone have been driven westwards along a plane that runs up Gleann na Muice, and truncates the underlying Lewisian Gneiss with its basic dykes.

Over a great part of the area between Loch an Nid and the Heights of Kinlochewe the exact position of the Moine thrust cannot be definitely determined, owing partly to the absence of sections in the direction of the dip of the strata, and partly to the mylonised rocks that so often accompany this great line of displacement. These mylonised materials have resulted from the shearing of gneiss and green epidotic grits. They are well developed near Loch a' Mheallain Odhair, two and a half miles north of the Heights of Kinlochewe, and also on the western slope of Sròn Dubh. But on the south-west declivity of Beinn Bheag, and particularly in the valley of Abhuinn Bruachaig, below the Heights of Kinlochewe, the Moine thrust is clearly traceable. Indeed, in the latter area, where the ground is bare of drift, the Eastern Schists above that plane of disruption pass transgressively across the displaced Lewisian Gneiss and the Torridon Sandstone with a small patch of the basal quartzites.

Beyond the Heights of Kinlochewe the structure of the country becomes remarkably complicated. A conspicuous example of this complexity may be seen on the rocky ridge on the north side of the Kinlochewe River (Fig. 4), where, owing to the inversion of the displaced materials, the folding of the Kinlochewe or Ben More thrust-plane, and the subsequent denudation of the rocks overlying that plane, the structure has been found most difficult to unravel. The western part of this section supplies another illustration of the uneven land surface on which the Torridon Sandstone reposes, the ridge of Meall Riabhach being flanked by pre-Torridonian valleys on

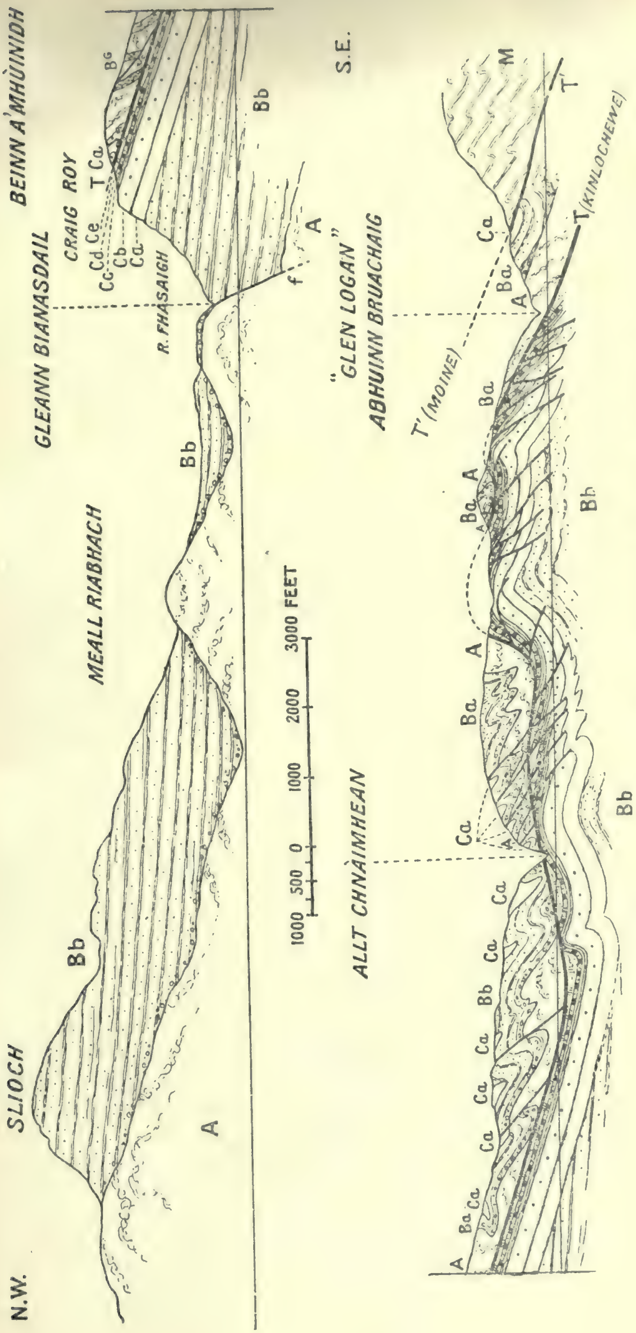


FIG. 4.—Section from Slioch by Beinn a' Mhùinidh to Abhuinn Bruachaig.

A. Lewisian Gneiss. B^G. Dykes in Gneiss. Ba. Diabaig Group (Torridonian). Bb. Applecross Group. Ca. Basal Quartzite (Cambrian).
Cb. Pipe Rock. Cc. Fucoid Beds. Cd. Serpulite Grit. Ce. Limestone. M. Eastern Schists. T. Thrusts. T'. Moine Thrust.
f. Fault.

either side. In Gleann Bianasdail the position of the Fasagh fault (f) is shown, whereby the Torridon Sandstone on the east side of the valley is let down against the hornblende-schists of Lewisian age to the west. Along the eastern slope of this valley runs the unconformable junction between the Cambrian quartzites (Ca, Cb) and underlying Torridon Sandstone (Bb). A normal sequence can here be followed from the basal quartzites to the members of the *Olenellus* zone (Cc, Cd), and in places to the basal dolomite (Ce).

On Craig Roy the succession is interrupted by the Kinlochewe (Ben More and Kishorn) thrust-plane (T), above which appear the Lewisian rocks (A) with an infold of the Basal Quartzite (Ca), the unconformable junction between the two being well exposed. About half a mile to the south of the top of Beinn a' Mhùinidh the Lewisian rocks are covered unconformably by the Torridon Sandstone (Ba), with infolds of the Basal Quartzite (Ca), arranged in isoclinal folds. The axial planes of these folds are inclined generally to the E.S.E., and are truncated in places by minor thrusts heading in the same direction. These red sandstones stretch eastwards from Meallan Ghobhar to the hills beyond Allt Chnàimhean (the burn of the bones), and cover more than a square mile of ground (see Sheet 92). Along their northern margin their unconformable boundary line with the gneiss has been traced, and they are found to be usually inverted and to pass underneath the older formation. The basal breccia at the line of junction contains fragments of the underlying gneiss.

The gorge in the lower part of Allt Chnàimhean has been cut by the stream through the overlying cake of thrust Lewisian rocks, Torridon Sandstone, and Basal Quartzite, so as to reveal the piled-up Fucoid Beds, Serpulite Grit, and basal dolomite beneath the Kinlochewe thrust-plane (T). The exposure of these successive layers of displaced materials is due not only to denudation, but partly also to the folding of the rocks above and below this line of displacement, as represented in Fig. 4. A still more striking example of this complicated structure occurs about half a mile to the east of Allt Chnàimhean, where the thrust-plane, together with the rocks which it separates, has been sharply folded, and where the thin veneer of gneiss and red sandstone overlying the thrust-plane has been removed from the crest of the arch. The dome-shaped arrangement of the Cambrian strata beneath that plane is well seen on the hilltop and southern slope facing the road that leads to Kinlochewe. The third subdivision of the Pipe Rock is the lowest Cambrian zone here represented. It is followed by the higher sub-zones, the Fucoid Beds and Serpulite Grit, which are repeated by reversed faults. Farther east, owing to a minor fold, a lobe of the displaced materials that lies above the Kinlochewe thrust-plane consists of gneiss with an infold of Torridon Sandstone. Although represented as an outlier in Fig. 4, it is really connected with the main mass. On the slope towards Abhuinn Bruachaig the bare plane of the Kinlochewe thrust is exposed, and for part of the distance the Lewisian Gneiss rests mainly on the Cambrian Limestone. Here, too, the inverted junction of the Torridon Sandstone (Ba) with the gneiss (A) above the line of displacement is visible, while to the south of the outcrop of the thrust-plane the repetition of the Fucoid Beds, Serpulite Grit and basal dolomite is clearly observable.

In the channel of Abhuinn Bruachaig, about two miles up the valley from Kinlochewe, the same important line of disruption is laid bare, where pink epidotic granitoid gneiss ("Logan Rock" of Heddle) is superimposed on the dolomite of the Ghrudaidh group, the upper *Salterella* band being visible within a few yards of the thrust-plane. Close by are the Fucoid Beds, which have yielded fragments of *Olenellus.* Farther down the stream the gneiss, exposed in several places, is associated with a mass of crushed Torridon Sandstone (Ba) in the triangular space between the Abhuinn Bruachaig and Glen Docherty. At one locality, as shown in Fig. 4, the crushed sandstone is succeeded by the Basal Quartzite (Ca) beneath the Moine thrust-plane (T′). Reference has already been made to the correct identification by Professor Bonney of the Lewisian Gneiss and Torridon Sandstone in Abhuinn Bruachaig ("Glen Logan"), and to the recognition of the reversed fault whereby the gneiss has been brought to the surface.

The horizontal section in Fig. 4 shows that the materials above and below the Kinlochewe thrust-plane, together with that plane itself, have been thrown into a compound anticline and syncline, and that the folding was developed subsequent to the thrusting.

Attention has already been directed to the great fault that runs along Loch Maree and up the valley of Glen Docherty, whereby the undisturbed strata, the successive thrust-planes, and the displaced masses, have been shifted north-westwards on the south side of the dislocation.

Along the south-west side of Loch Maree, in the undisturbed Torridon Sandstone in Glen Grudie, we find the prolongation of the Fasagh fault, which has been

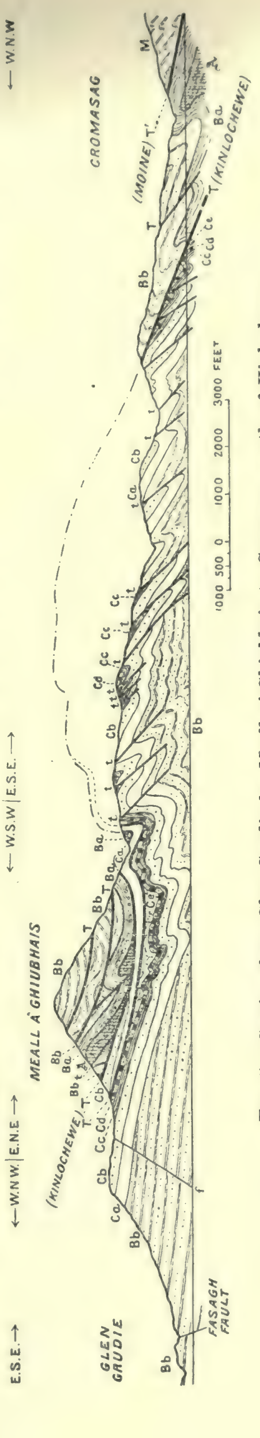


FIG. 5.—Section from Glen Grudie by Meall a' Ghiubhais to Cromasag, south of Kinlochewe.

A. Lewisian Gneiss. Ba. Diabaig Group (Torridonian). Bb. Applecross Group. Ca. Basal Quartzite (Cambrian). Cb. Pipe Rock. Cc. Fucoid Beds. Cd. Serpulite Grit. Ce. Grudhaidh Limestone. M. Eastern Schists. T. Thrusts. T′. Moine Thrust. t. Minor Thrusts. f. Normal Faults.

shifted about three miles to the west of its position in the Fasagh Glen at the head of the loch. On the eastern slope of Glen Grudie (see Fig. 5) undisturbed Cambrian strata, ranging from the Basal Quartzites to the Serpulite Grit (Ca to Cd), and in places to the basal dolomite (Ce), dip in an easterly direction at angles varying from 10° to 20°. These unthrust strata are abruptly truncated by the Kinlochewe thrust, and are overlain by a large mass of Torridon Sandstone (Ba, Bb) with inliers of Lewisian Gneiss (A), which together cover an area of a square mile and a half round Meall a' Ghiubhais. This prominent hill (2882 ft.), about two miles to the west of the head of Loch Maree, forms a conspicuous outlier of displaced materials. The thrust-plane on which these materials lie can be traced round the mountain, where it appears as a circular fault or line of discordance between the rock masses. It is worthy of note that on the south-west side of the hill, not far from the line of section (Fig. 5), the basal quartzite is seen to rest unconformably on the Torridon Sandstone as an infold above the Kinlochewe thrust-plane. While the Torridon Sandstone rests on unthrust Cambrian strata on the north and north-west, a slice of Basal Quartzite and Pipe Rock, which has been driven westward by an intermediate minor thrust, comes beneath the thrust-plane on the south and east, as shown in Fig. 4, and is recognisable from a distance owing to the white fringe which the strata form beneath the darker overlying sandstone.

In this outlier the Diabaig and Applecross groups of the Torridon Sandstone are both represented, the strata being arranged generally in the form of a syncline with a compound anticline towards the west. The members of this formation are traversed by minor thrusts, one of which has been traced round the hill. They rest on the Lewisian Gneiss, which, as shown in Fig. 5, appears in places between them and the thrust-plane. The strata are here not much deformed, except near the thrust-plane and the other minor displacements. Where the arkose has become slightly schistose, the dark and grey shales have been cleaved, and along the actual lines of movement the strata have been transformed into flinty crush-rocks.* A small patch of displaced Torridon Sandstone that lies to the east of the main outlier on Meall a' Ghiubhais rests partly on Basal Quartzite and partly on Serpulite Grit.

Eastwards for a distance of two miles the Cambrian zones up to the Serpulite Grit are repeated by inverted folds and reversed faults, their general inclination being towards E.S.E. and E. The underlying Torridon Sandstone has shared in these plications, for, on the wooded slopes facing Loch Maree and in the cliff above, the members of that system, not much deformed, can be seen to rise from underneath the quartzite in great flexures, and along the line of section (Fig. 5) in sharp isoclinal folds.

About a mile up the valley from the head of Loch Maree the main outcrop of the Kinlochewe thrust appears, where the Torridon Sandstone (Bb) is superimposed on the Cambrian Quartzites. The grits are schistose in places, the planes of schistosity being inclined at higher angles than the planes of bedding. This flaser structure becomes more conspicuous as the sandstones are followed up the Kinlochewe River beyond Cromasag (Sheet 82). The position of the Moine thrust is concealed by alluvium, but the green schists that overlie it are exposed in the river close to the Kinlochewe Hotel (Sheet 82). B. N. P., J. H.

---

* The rocks forming the "sole" of the thrust-plane at this locality have not been much affected by the movement. In one place, close to the spot where the Fucoid Beds have yielded the finest specimens of *Olenellus*, the basal dolomite is so little disturbed, that within two inches of the thrust-plane the well-rounded grains of sand and the tubes of *Salterella pulchella*, which characterise the zone, are uncrushed.

CHAPTER VII.

THE EASTERN SCHISTS.

THE Eastern Schists, as already indicated in the general geological description of this region (p. 10), comprise (1) mylonised rocks; (2) granulitic quartzose schists and muscovite-biotite-gneiss or schist, representing the psammitic and pelitic types of the Moine Series; and (3) a limited development of micaceous and hornblendic rocks, resembling in some particulars types of Lewisian Gneiss in the areas to the west of the post-Cambrian movements in Ross-shire.

The feature of exceptional interest presented by the Eastern Schists is the sequence of rock groups and their structural relations as worked out by the Geological Survey in the Fannich Mountains and in the tract immediately to the north.

In the "Summary of Progress for 1897," Mr. Gunn described the area mapped by him between the valley of the Broom and the watershed of the Fannich Mountains. He there advanced (p. 38) an order of succession in the schists of the Moine Series, the lowest subdivision occurring near the Moine thrust. He pointed out that the highest member of the series, consisting of muscovite-biotite-gneiss, was overlain by coarse acid gneisses of Lewisian type with basic lenticles and bands of diorite, exposed along the northern slopes of the western part of the Fannich range. From the distribution of these rocks he inferred that they form the northern end of a great synclinal fold.

From Fannich Lodge, in 1898, Dr. Horne mapped part of the ground between Loch Fannich and the watershed of the Fannich range, when he identified the various rock groups previously described by Mr. Gunn. In the "Summary of Progress of the Geological Survey" for that year (pp. 11–15), he showed that these groups could be traced, at high inclinations, from the watershed south to Loch Fannich along the eastern limb of the fold, and that the subdivisions of the Moine Series rise from underneath the gneisses of Lewisian type along the western limb. Regarding the superposition of the acid gneisses of Lewisian type on the Moine Series, he stated that two hypotheses may be advanced to explain the relationship: (1) that the structure may be analogous to that north of Loch Maree, where the biotite-gneisses and hornblende-schists of Meall Riabhach are superimposed on the sedimentary series of Letterewe; and (2) that the structure may be fan-shaped, the rocks of Lewisian facies, though apparently the highest, being in reality the lowest, while the sequence of the other groups may be deceptive. From the uniform characters and persistence of the siliceous members of the Moine Series throughout the folded area of Fannich he suggested that their crystalline characters were probably developed before the post-Cambrian movements.

In 1899 Mr. Gunn continued the mapping of the Eastern Schists to the north and Dr. Horne to the south of the Fannich watershed, when further additions were made to our knowledge of the structure of the range. Mr. Gunn* observed that, south of Loch a' Bhraoin, the acid gneisses of Lewisian type are themselves overlain by garnetiferous muscovite-biotite-gneisses resembling the pelitic gneiss of the Moine Series immediately underlying these gneisses. He further noted that the grade of metamorphism presented by the pelitic gneiss of the Moine Series (Meall an t-Sìthe rock) and the overlying acid gneisses of Lewisian type is high, compared with that in the siliceous flaggy schists of the Moine Series. If the metamorphism was induced from below, it could hardly be due to any alteration of the rocks in their present positions, for highly altered masses overlie others which are less altered. Mr. Gunn suggested two explanations: (1) that notwithstanding the apparently regular order of succession now existing, the rock groups are really inverted; and (2) that the more highly altered rocks owe their present abnormal positions to a lateral thrust, but no trace of any such line of movement had been found by him.

In the course of his field work in the western part of the Fannich group in 1899,† Dr. Horne found that the acid gneisses of Lewisian type are inclined at gentle angles in an easterly direction, and that, owing to the flat folding, they there present a highly sinuous outcrop. He also noted that the characteristic muscovite-biotite-gneiss of the Moine Series overlies and underlies the belt of acid gneiss, both outcrops being regarded as repetitions of the same band due to folding. From the mapping of the tract south of the watershed he inferred that the groups of crystalline schists identified by Mr. Gunn are repeated on both limbs of a fold of great amplitude, and that in the western part of the area at least the axial planes of the folds must lie at comparatively low angles (see Plate II., Sections A. and B.).

J. H.

AREA NORTH OF THE FANNICH WATERSHED.

In the area between Loch Broom and the Fannich watershed, the following order of succession has been determined:—

(𝔄) Grey acid gneiss, much of it coarse in character and very like some varieties of the Lewisian Gneiss. It contains basic lenticles and bosses and broad bands of diorite or epidiorite, some of which may be of the nature of dykes.

(1) Massive brown-weathering biotite-gneiss, generally crowded with small white pegmatites, and containing many large and small garnets. There are also some irregular masses of dark garnet-hornblende-rock associated with it. This group is apparently several hundred feet in thickness. It has been termed the Meall an t-Sìthe Rock.

(2) Granulitic quartzose schist or gneiss, flaggy, fine-grained, light-grey or white in colour; mainly composed of quartz and felspar with a little mica. In the following description, it is referred to as

---

* "Summary of Progress for 1899," *Mem. Geol. Surv.* (1900), pp. 10–14.

† *Op. cit.* pp. 8–10.

the Meall a' Chrasgaidh Rock. The members of this group have apparently a thickness of from 1200 to 1500 ft.

(3) Biotite-schist, dark-coloured, of a pelitic character, with occasional small garnets (Sgùrr Mòr Biotite-schist). It includes a strong band of quartzose granulitic schist. The group appears to be altogether nearly 2000 ft. in thickness, made up of

Biotite-Schist	1250 ft.
Quartzose Schist	200 „
Biotite-Schist	500 „

(4) A thick group of light-coloured, flaggy, granulitic quartzose mica-schists, with occasional thin bands of dark-coloured biotite-schist. This group occupies the larger part of the area surveyed, and is apparently several thousand feet in thickness. It is the typical Moine Schist.

As before noticed, these rocks are disposed in a synclinal form about the watershed at the head of the valley of the River Broom. Group 𝔄, with rocks resembling Lewisian types, occupies a considerable area between Sgùrr Breac and Sgùrr nan Clach Geala. The gneisses there dip at a high angle, being often vertical, and strike north-west and south-east. It is difficult to determine the relation between the members of this group and those of group 1, but the divisions from No. 1 to No. 4 form a regular and apparently descending series which successively crop out to the north of Loch a' Bhraoin with a southerly or south-easterly dip. Traced westward, they approach the Moine thrust near Loch an Nid, where they turn southward, and the upper part of division No. 4. abuts against the line of thrust. It is evident that in the area north of Loch an Nid there is no exact parallelism between the line of the Moine thrust and the strike of the foliation in the schists, for as we proceed in this direction towards Loch Broom lower and lower parts of this division successively crop out, so that whatever may be the age of these schists they existed as such prior to the formation of the Moine thrust-plane.

Group 𝔄.—The rocks of this group are typically developed at the head of Allt Brebaig between Sgùrr Breac and Sgùrr nan Clach Geala, and the coarse-grained grey acid gneiss has a decided north-west strike. Generally the gneiss is of a very acid type; some parts of it which are granulitic might at first sight be considered to belong to the Meall a' Chrasgaidh rock, if it were not for the presence of basic bands. A grey granulitic rock (7510) with a marked linear foliation, which is found in the eastern branch of Allt Brebaig 1500 yds. north-east of Sgùrr Breac, is composed of quartz, felspar and two micas with sphene as an accessory. Not far west of this place, in the burn called Allt nan Eilig (the other branch), is a well-banded grey and cream-coloured rock (7509), which is an epidote-pyroxene-granulite. It contains epidote in grains and crystals, pale-green pyroxene, hornblende (scarce), water-clear felspar and quartz, forming an irregular mosaic, with sphene as an accessory.

About a quarter of a mile farther up the same stream occur coarse-grained massive rocks of a basic character. One of the broad black bands (7508) is a granitoid aggregate of green or greenish-brown hornblende and oligoclase, with some sphene. These basic rocks appear to have the characters of intrusive dykes, and bear the same relation to the acid gneiss as the epidiorite dykes do to the Fundamental Complex in the area west of the post-Cambrian displacements. They have been traced for about two miles in a north-west and south-east direction. Their total width is between 100 and 200 yds., and in some places they appear to be wholly of basic material, while in others thin strips of acid gneiss divide them into well-marked bands.

A somewhat different type of basic rock also occurs in association with the acid gneiss. It is represented by lenticles of basic material, and irregular lumps and thin bands of hornblende-schist, which seem to bear the same relation to the acid gneiss of the district as the earlier basic rock does to the acid types of the Lewisian Gneiss in the west of Sutherland and Ross.

The rocks of this area are much folded, a beautiful example of which on a large scale occurs in the crags to the south-west of Sgùrr nan Clach Geala. In ascending the stream Allt Leac a' Bhealaich, three-quarters of a mile S.S.W. from the hilltop, a band of epidiorite is encountered about 30 yds. in breadth, and, 300 yds. farther up, another band 70 yds. broad is met with, having a strip of gneiss 50 ft. wide in the middle of it. The foliation in the gneiss in this locality dips uniformly and steeply towards E.N.E. As the broader band is followed northward for about half a mile to the great precipice of Creag an Fhuarain, on the south-west slope of Sgùrr nan Clach Geala, the included strip of gneiss disappears, and we find a single broad dyke of about 100 yds. The smaller basic band widens out also to some extent as it is traced northward into the same crag, where the two are found to form two separate limbs of one isoclinal fold which curves round and spreads out over the crag in a dark basic mass. The foliation in the adjoining gneiss and the occasional foliation in the dyke itself exhibit the structure clearly. In one part of the crag the breadth of the mass of epidiorite is quite 800 ft. At the head of Coire Breac, to the north-west of Sgùrr Breac, the folding is so intense that the acid gneiss is felted with the garnetiferous gneiss of group 1, and both are traversed by numerous pegmatites. Various acid bands met with in the garnetiferous gneiss around Loch Toll an Lochain and on A' Chailleach appear to be folded portions of group 𝔄, as the two acid bands seen in Allt na Goibhre (the stream flowing northward from Loch Toll an Lochain) certainly are. The highest of these forms a marked feature in its outcrop on either side of the burn, and it can be distinctly traced round as a coarsely crystalline rock to the west side of A' Chailleach, where a thinner band of a similar character appears below it to the westward. The lowest of the two acid bands in Allt na Goibhre, which is of considerable width in the burn, seems to disappear when followed westwards. On the east side of the burn it is probably connected with the main mass of acid gneiss.

No basic igneous rocks were noticed in the acid bands under A' Chailleach, but the two acid bands in Allt na Goibhre both contain dark basic hornblendic masses. In the uppermost band some of the basic masses are foliated, and in one excellent section the foliation of the acid gneiss cuts across that of the included basic rock nearly at right angles—a structure almost exactly similar to that so often seen in the Lewisian Gneiss of the Gruinard district.

Group 1.—The Meall an t-Sìthe rock has a peculiar character, and is quite unlike the ordinary type of Moine Schists. It is so full of large garnets that in some places a layer of them is spread over the ground, as the result of the decomposition of the rock, and once after a heavy spate in Allt na Goibhre, which runs into Loch a' Bhraoin from Loch Toll an Lochain, a bed of garnet sand was found in the delta of the stream. On the north side of Loch a' Bhraoin this rock, stretching from Meall Dubh, a hill about half a mile E.S.E. of Creag Rainich, to Meall an t-Sìthe, forms an outlier, probably faulted on the south-east side (Plate III., Section B., group 1). To the south of this loch the rock stretches as a marked band high up on the hillside from the western shoulder of A' Chailleach round to Allt Brebaig—the stream that rises on the north slope of Sgùrr Breac—crosses the valley, and forms the southern declivity of Meall a' Chrasgaidh, whence it strikes southward with a high westerly dip over the top of Sgùrr nan Clach Geala, 3581 ft., the second highest hill of the district.

The garnetiferous gneiss outlier of Meall an t-Sìthe, which is three miles in length, extending westward to near Creag Rainich, lies in the centre of a small syncline. The rock is often massive in appearance, and is largely made up of small irregular bands of white or grey pegmatite, which for the most part are parallel to the foliation planes of the rock. Irregular bosses and sills of a basic intrusive rock are often met with.

For some distance on either side of the fault that crosses Allt na Faine (a tributary of the Dundonnell River), about a mile and a quarter north-east of the top of Creag Rainich, the exact base of the garnetiferous gneiss is concealed by drift. But after passing over the obscure ground to the south-west the line between this rock and the quartz-schists is remarkably clear and straight, and the dip is steadily E.S.E. at angles of 10° to 20°. Nearer the centre of the syncline, however, the outcrops of the rock are not so clear and the dip is irregular.

Near the northern edge of this mass bands of a very acid schist or gneiss occur quite different in character from the rest of the rock. The largest and most important of these, visible about a mile slightly south of west of the top of Meall an t-Sìthe, is almost certainly an infold of the siliceous rock No. 2, which apparently lies below.

Good sections of the garnetiferous gneiss are found in the crags all along the northern boundary, but perhaps the finest continuous exposure occurs in the crag on the south side of Loch a' Bhraoin from near the burn called Allt na Goibhre, which issues from Loch Toll an Lochain, round to Allt Brebaig eastward. In the latter locality, near its upper boundary the rock is comparatively free from garnets, is more evenly foliated than usual, and contains abundance of white mica with little biotite. A good exposure of the garnetiferous gneiss appears in Allt na Goibhre, but to the westward the boundary between it and the siliceous flags is much obscured by drift for a long distance, only small isolated outcrops occurring; but on the west side of A' Chailleach the rock is again exposed at the surface.

In Allt na Goibhre, above the uppermost of the two bands of acid gneiss (group 𝔄), the Meall an t-Sìthe rock, or one very similar, crops out in great force. It occupies the whole of the valley, spreads over the bounding ridges on either side, and forms the upper parts of

A' Chailleach and Sgùrr Breac with the high ground between them, thus occupying the watershed for a distance of two miles. On these hills, owing to the rarity of the small pegmatitic bands, the rock occasionally resembles a biotite-schist.

Only brief references may here be made to the intrusive igneous rocks of these groups, as they have for the most part been described in the account of the strata in which they occur. Those found in the acid gneiss (group 𝔄) are generally massive epidiorites or hornblende-schists; the bosses and sills of basic material associated with the garnetiferous gneiss (group 1) are generally hornblendic in character and full of garnets. These garnets have generally no crystalline form, being more or less rounded aggregates of garnet-rock. In places they attain a large size; masses which are as much as 3 to 4 ins. in diameter having been met with.

The small pegmatites, composed of quartzo-felspathic material, which are generally extremely abundant in the garnetiferous gneiss, must be considered as segregations from the adjacent gneiss, but it is doubtful if some of the larger pegmatites are not intrusive in character. On the east side of Toll an Lochain and elsewhere masses of coarse pink and white pegmatite have a dyke-like form, and several of them which are many feet in width can be traced for a considerable distance. They generally run along the strike of the foliation, but some may be seen to penetrate both the garnetiferous muscovite-biotite-gneiss (group 1, Plate II.) and the acid gneiss of Lewisian type (group 𝔄, Plate II.). They are very conspicuous in Druim Réidh to the east-north-east of Loch Toll an Lochain, where they are mainly composed of microcline felspar.

Group 2.—The Meall a' Chrasgaidh rock is perhaps rather more siliceous than the typical Moine Schist and contains less mica. This band of flaggy quartz-schist occupies the upper part of the valley of the Dundonnell River (Allt na Faine), where it is crossed by a rather large fault running north-west with a downthrow to the south-west. The beds there dip to the east-south-east and south-east, but near Creag Rainich, at the head of the valley, they curve round and run across the ridge to the south, while the inclination changes to a northerly direction along the north side of Loch a' Bhraoin. Hence the band forms a synclinal fold, in the centre of which, and forming the highest ground, is the garnetiferous gneiss (No. 1, Plate II.). Numerous sections of these flaggy quartz-schists are exposed in the small streams on the north side of Loch a' Bhraoin. On the north side of Meall an t-Sìthe the rock appears with a southerly dip of 10° to 20°; it sweeps round the shores of Loch a' Bhraoin, and, eastward, forms a band varying from a quarter to three-quarters of a mile in width, parallel to the outcrop of the rocks above and below. There is a good section of it in the river east of Loch a' Bhraoin, but the best section is in the scars of Meall a' Chrasgaidh, and from this hill it strikes almost due south with a westerly dip of from 30° to 50°. There is a marked band of biotite-schist in the lower part of the group under Meall a' Chrasgaidh. No intrusions of igneous material and very few pegmatites have been met with in these siliceous schists.

Group 3. *Sgùrr Mòr Biotite-Schist.*—This group generally forms a much broader belt than either of the two preceding, and, owing to folding and repetition by faults, it spreads over a much larger area. In addition to the broad band that accompanies the Meall a' Chrasgaidh rock, circling round it from the north-west to east, this biotite-schist appears on each side of the Broom valley about Garvan, and a remarkable outlier of it forms the hills of Beinn Enaiglair and Meall Doire Fàid to the east of Braemore. This biotite-schist in several places appears to be much more plicated than the quartz-schists that border it on either side, which may be due to the former having been of a softer character, so that it yielded much more readily to pressure. Fine sections are exposed in the crags about Loch a' Mhadaidh, particularly in the scar under Càrn na Crìche, which is 1000 ft. in height, and almost vertical. It forms the peak of Sgùrr Mòr, 3637 ft., the highest hill in the Sheet. The felspathic biotite-schist (7514) here is dark-coloured and contains very little quartz; and the felspar is water-clear and for the most part untwinned (near andesine). The rock may be examined in Abhuinn Cuileig to the east of the foot of Loch a' Bhraoin, where there is a fairly good section of it. The zoisite-rock hereafter described occurs in the schist here near the foot of Allt an Eas Bhig, which drains the northern slope of Meall a' Chrasgaidh and flows into Abhuinn Cuileig.

In the streams to the north-west of the head of Loch a' Bhraoin, a band of biotite-schist probably represents this rock, or is a part of it. It has been traced over Creag Rainich, thence southwards and eastwards round the synclinal fold to the head of Loch a' Bhraoin. On the watershed to the south-west of A' Chailleach, a band of biotite-schist occurs, which may be the continuation of that just referred to. It has been traced northward into the streams that run into the head of Loch a' Bhraoin from the south.

The band of quartz-schist which is found in the Sgùrr Mòr biotite-schist is strongly developed to the south of Loch a' Mhadaidh, under Càrn na Crìche and Sgùrr Mòr, and it may be followed at intervals westward to Abhuinn Cuileig, beyond which it is lost in the peat moors. On the other side of the fault running from Loch a' Bhraoin to Garvan in Strath Broom we find it north-east of Fain about Loch an t-Sìthein and Càrn Breac Mòr, the top of which is an outlier of biotite-schist, and it can be followed to the Broom valley, where it is, like the biotite-schist above and below, much broken by faults. On the east side of the valley it appears above Glackour, where several streams have cut gorges through it. This band is not very unlike the Meall a' Chrasgaidh rock, but, in some places, appears more massive.

The part of the biotite-schist which comes below this zone of quartz-schist is generally not so free from siliceous intercalations as the main mass which lies above it, and towards the base appear alternations of quartz-schist with biotite-schist, so that the boundary in some cases is rather conventional. It is the lower part of the large biotite-schist mass that spreads out by plications over Creag Dhubh to the south of Abhuinn Droma, and that forms the outlier of Beinn Enaiglair and Meall Doire Fàid to the north of that stream. The same rock is traceable from Fain on the Dundonnell River to the Broom valley, and we find it again east of the Broom, rising from Glackour and passing above Inverbroom Lodge to Strone Nea, whence it trends eastward, to be cut off by the large Allt a' Bhràighe fault. This fault bounds the biotite-schist group on the east, and the lower part particularly here spreads over a considerable area, where it may be easily studied in Allt a' Bhràighe and in the burns to the northward. The rock in this portion of Allt a' Bhràighe is almost free from quartz, and is dark-coloured, with abundant biotite. A specimen of the rock (7500) from the side of the path in Braemore Wood, nearly 800 yds. south-east of Glackour, contains biotite in fairly large flakes, felspar, almost entirely oligoclase, garnet and a little quartz.

Irregular veins of a white pegmatite are rather common in places in this schist, and perhaps they are more numerous about Meall Doire Fàid than anywhere else. One of these, from beside the footpath in Braemore Wood (7499), near Allt a' Bhràighe and three-quarters of a mile S.S.E. from Glackour, is a coarse-grained aggregate of quartz, oligoclase and biotite in biotite-schist. Under the microscope the oligoclase is very abundant and in large individuals.

It appears most probable that this and other pegmatites of a like kind are not intrusive but formed by segregation. In parts of the district where there are frequent alternations of biotite-schist with quartz-schist, pegmatites are met with in the former rock, while in the latter quartz-veins seem to replace the pegmatites.

In the biotite-schist in many places a peculiar rock largely composed of zoisite occurs, and deserves a somewhat extended notice. It is found in thin bands from half an inch to two inches in thickness, which are frequently met with on the north side of Allt a' Bhràighe. The bands appear always to lie along the foliation planes of the schist, and when the latter is folded the bands are folded also. One of these bands occurs on the west side of the footpath in Braemore Wood, nearly 800 yds. south-east of Glackour, and a specimen of it was submitted to Dr. Teall for microscopical examination, who has furnished the following description of it:—

(7501.) "A moderately coarse-grained, dark, banded rock. One band contains rude prisms of zoisite often measuring 7 or 8 mm. in length, and showing no tendency to a definite orientiation. Small crystals of garnet (2 mm.) are also common. Under the microscope, zoisite, garnet, sphene, rutile, actinolite, and a granulitic quartz-albite (?) mosaic are observable. The zoisite occurs in long and somewhat irregular spindle-shaped individuals, often measuring 7 or 8 mm. by 1 or 2 mm. in the broadest part. These are micro-poikilitic in consequence of the presence of numerous inclusions of quartz. Garnet occurs in idiomorphic crystals and also contains inclusions. Both in the garnet and zoisite the inclusions are more numerous in the central than in the marginal parts. Actinolite is present in long slender prisms; sphene as granules crowded together in streaks; rutile in detached grains and crystals. The matrix of the rock is a granulitic mosaic of quartz and untwinned felspar, presumably albite."

Another specimen (7502) from the west side of Allt a' Bhràighe above the wood showed the junction of the zoisite-rock with garnet-biotite-schists, the latter consisting of a granulitic mosaic of quartz and felspar (·1 to ·2 mm.), flakes of biotite (average size about 1 by ·2 mm.) and idiomorphic garnets (1 to 2 mm.).

A somewhat different specimen showing the junction of the two rocks was taken from the west side of Allt a' Bhràighe 300 yds. above the wood. This is fully described by Dr. Teall below.

(7503.) "Banded gneissose rock studded with small red garnets. Bands light and dark; the former highly quartzose, the latter rich in garnet and biotite. Examined with the microscope, some large irregular patches of zoisite are seen, associated with the quartz in the lighter bands. The dark band immediately adjoining the light bands is composed of garnet, green hornblende, epidote in small grains and crystals, biotite, sphene. This band, if it occurred by itself, would be a garnet-epidote-amphibolite. Other portions of the slide are formed of garnet-biotite-schists, with accessory epidote and hornblende. Taken with the other specimens it proves that there is no sharp line between the garnet-amphibolites and the biotite-schists. The two types of rock are intimately interbanded and shade into each other."

Though the zoisite-amphibolite is most abundant in thin bands near Allt a' Bhràighe and some other streams to the northward, it has also been found to the east of Loch a' Bhraoin in the River Cuileig near the foot of Allt an Eas Bhig, and on the west side of the Broom valley to the north of Càrn Breac Meadhonach, about half a mile W.N.W. of Càrn Breac Beag. In all cases it is associated with the same broad band of biotite-schist. It has not been noticed in the quartzose type of Moine schist.

Since the discovery of these zoisite-amphibolites and zoisite-granulites in the Eastern Schists of Sheet 92, similar bands have been met with in the Moine Series in other parts of the Highlands. They usually occur in the coarser pelitic schists, which are believed to be altered sediments of a somewhat calcareous character.*

Along its eastern edge the mass of biotite-schist (group 3) becomes involved in the north-and-south series of plications subsequently described, so that its eastern boundary in the outlier on Beinn Enaiglair and Meall Doire Fàid is an inversion, as is also that from Creag Dhubh to Loch a' Mhadaidh, south of Abhuinn Droma.

Group 4.—The greater part of the rock comprised in this division is more or less quartzose, and somewhat similar to the Meall a' Chrasgaidh rock (group 2) above described. Felspar appears to be generally present. Some portions are very siliceous and rather massive, with little or no mica, and might be described as quartz-schist, but there is generally some biotite in the rock, and often both black and white micas are present. The mica is most abundant along the foliation planes, which causes the rock to split into flags, varying much in thickness. Along the road up the Broom valley, between Allt a' Bhràighe and Allt na h-Ighine, as many as 36 distinct bands or beds may be counted in a thickness of 6 ft. of rock. In another place by the roadside close to the 11th milestone, which is about three-quarters of a mile down the valley from Braemore Lodge, there are 22 different beds in a section 7 ft. in height, giving an average of 4 ins. to each. The amount of mica varies greatly, so that while on the one side the rock graduates into quartz-granulite, on the other, by becoming poor in quartz and rich in biotite, parts of the rock assume the character of a biotite-schist. In many places there are extremely thin partings of the latter rock separating the beds of quartz-schist from each other. On a weathered section the quartz-schist beds project while the partings recede.

These quartzose flags are all granulites. A grey flaggy specimen (7513) from near Inverbroom bridge is a biotite-granulite, biotite being the most abundant mica. When both micas are present in about equal proportions, as in a specimen (7518) from the burn east of Braemore Lodge, the rock may be called a mica-granulite. Occasionally epidote is present in small grains, and, in another specimen (7517) from the same locality, is abundant enough to warrant the use of the term epidote-biotite-granulite. A specimen (7516) from the roadside 650 yds. west of the 13th milestone * from Ullapool contains quartz, felspar, biotite, and white mica, with epidote and garnet as accessories. In the quarry at the 13th milestone is a fine-grained flaggy quartzose rock (7515) passing into mica-schist. This is described as " A central band almost entirely composed of quartz and felspar; biotite and garnet present as accessories. This band passes gradually into one richer in biotite, and containing numerous granules of sphene and a few grains of epidote."

---

* "The Geology of Glenelg, Lochalsh, and South-east part of Skye," *Mem. Geol. Surv.* (1910), p. 52; "The Geology of Ben Wyvis," etc., *Mem. Geol Surv.* (1912), p. 19; *Quart. Jour. Geol. Soc.*, vol. lx. (1904), p. 410.

The following is a more detailed description of the general appearance of the rocks of this quarry near the 13th milestone from Ullapool to Garve. The rock is a grey, flaggy, siliceous mica-schist, in well marked bands varying from 2 ins. to about 6 ins. in thickness. There is abundant white mica on the planes of separation (or foliation), but the mica scattered indiscriminately through the mass of the rock appears mostly to be black mica or biotite. The thinner bands are the most micaceous; some of the thicker have very little mica except on the planes along which the rock splits, and show little or no tendency to split up into thin laminæ parallel to these planes. There are apparently traces of garnets in places. The rock is evenly flaggy, and shows no sign of folding or contortion, though sharp contortions in a north-and-south direction occur to the west and to the east of it, especially on the latter side, as it is near the line where intense overfolding commences.

Examples of the two extreme types of schist are to be had side by side in the burn 200 yds. below the Home Loch, Braemore. One of these (7504) is a dark, wavy, felspathic mica-schist containing two micas, quartz, felspar, with sphene as an accessory. The other is a grey biotite-granulite (7505) with abundant quartz, felspar and biotite. Garnet and zircon occur as accessories; the grains of the latter are numerous, and probably in the form in which they were deposited. This is a highly quartzose rock.

Some of the broader mica-schist bands that alternate with the thick quartzose granulites have been occasionally mapped. They closely resemble the thick biotite-schist of Sgùrr Mòr, and some of them make distinct features. Where the dark biotite-schist forms but a small part of the mass of the rock, it often covers an area quite out of proportion to its thickness. In places where thick beds of siliceous schist repeatedly alternate with thin bands of biotite-schist, it is almost invariably the rule that the former composes the small crags and features, while the latter forms a thin capping to the other at the top of the crag and spreads out over the dip slope.

Repeated alternations of these two types of schist sometimes compose broad belts of ground the general course of which can be indicated. Thus a strip of this character bounded by rocks of a pronounced siliceous type runs from Lochan Fada in the Dundonnell Forest in a north-east direction across the Dundonnell River, by Lochan Fraoich, Càrn a' Bhiorain, and the slopes of Meall a' Chàirn towards the head of Loch Broom. It appears in the ground north of Loch ri

---

* This milestone is about a mile and a quarter above Braemore Lodge.

Creagain to the east of the loch, and passes north-eastward to Meall Dubh, where all the rocks are much plicated.

The number of fine sections in the quartzose type of this group is so great that one can only notice the more important. The fine gorge of Braemore, which is so striking an object from the coach road, and the one almost as good on the western branch of the river (or Abhuinn Cuileig), where the rocks dip gently southward, exhibit many hundreds of feet of evenly-bedded, flaggy, siliceous rock. Below the large fall in the former ravine there is a marked long joint (or fault ?) running close to the south side of the stream and parallel with it. Near the principal bend in the stream farther down, the rock has been bared for a long distance above the road by the bursting of a dam at the Home Loch some years ago. The lower part of Allt na h-Ighine gives a good section, and so do the smaller streams to the southward. Perhaps the finest long section is afforded by the scars which range on the south side of the River Lael from opposite Inverbroom eastward to Beinn Dearg for a distance of from four to five miles with a height of 1000 ft. or more in places. The dip of 10° to 20° in these rocks is directed towards S.S.E. near the Broom valley, but gradually changes to south-west in the higher part of the Lael valley, where the angle of dip is also somewhat greater; and eventually the rocks become involved in a rapid series of north-and-south plications at the head of the valley. Farther north the lower parts of the Ardcharnich Burn and of Allt Raon a' Chroisg also afford good sections; and most of the streams on the west of Loch Broom run in rocky channels, but none are so good as those mentioned. Allt a' Chàirn, which falls into the Dundonnell River, crosses the strike of a broad tract of these rocks and gives a good section. The gorge is traversed for a long distance by a fault which is accompanied by a good deal of brecciation. The general dip is here 15° to 20° to south-east or E.S.E. The finest exposures of rock are south of the stream in numerous crags.

The Dundonnell River cuts for a long distance across the strike of the rocks and affords a fair section, but the most striking part of the gorge which it forms is impassable. To the east of the river, where its course is nearly north and south, is a conspicuous crag called Creag Dhubh Coill' a' Bhun, about a quarter of a mile west of Càrn a' Bhiorain and Loch Allt Eigin. In this scar many hundreds of feet of strong quartzose schist are exhibited. Thin bands of a darker colour, noticeable here and there, are beds of biotite-schist from 1 to 3 ft. in thickness. The beds have the usual E.S.E. dip about 20°, and in several places the rocks are crossed by crushes or faults which cause gullies in the crag. These range in direction from nearly due east to north-east. As we pass up the stream, the beds seen in the crag one after another cross to the opposite side, forming a series of pretty waterfalls, which are largest nearer the bridge at the end of the gorge. Near the bridge also the dip of the rocks is higher, being in places from 50° to 60°.

The contrast between the gently dipping flaggy rocks of the Braemore gorge, and the same rocks two miles to the eastward brought up in a rapid series of steep inverted folds, is very striking. A good view of the ground where these complications begin may be had from the pony-track in the forest about half a mile south of the lodge. On looking eastward to the rocky country north of the old road and east of Allt Doir' a' Mhuillin (3rd stream east of lodge), it may be seen that all the prominent features run in a north-and-south direction, which is quite different to what we find in the ground to the west. This is mainly due to the fact that a series of sharp folds or contortions which run nearly north-and-south begin in that area and increase in number to the eastward. There appears to be comparatively little folding in the siliceous schists east of the Home Loch. They dip eastward at low angles—5° to 10°—and the outcrops make small strike features, but we cannot advance far into the biotite-schist towards the east without finding evidence of considerable folding which increases in that direction. The majority of these plications are flattened overfolds, the result of which is to give a series of practically flat beds, so that as we trace the southern boundary of the biotite-schist on Meall Doire Fàid we find it runs nearly horizontally along the hillside in a south-east direction. This continues till we reach its eastern edge, where, owing to the high inclination of the inverted folds, the boundary runs almost due north for a long distance.

Good examples of the forms of folds may be seen in many places over the eastern part of Meall Doire Fàid, especially to the east of the Ordnance Station, where the biotite-schist contains a good many quartz-veins and whitish pegmatites. In the Abhuinn Droma, near the foot of Allt Leacachain, there is a very fine section of a similar series of folds in the siliceous schists which apparently underlie the biotite-schist. Perhaps the most instructive section of all is that in a scar about 150 yds. north-east of the 13th milestone from Ullapool, which shows how the gently-dipping siliceous schists to the west become inverted and form a series of sharply-folded rocks to the east.

The forest path which runs between Beinn Enaiglair and Meall Doire Fàid crosses the biotite-schist and affords an interesting series of sections. It passes close to good exposures of the evenly-bedded flaggy quartz-schist in the upper part of Allt a' Chumhainn above the Home Loch, where the burn runs in gorges. These beds have a low easterly dip. Beyond the biotite-schist, about a quarter of a mile west from Loch Féith nan Cleireach, we find the siliceous rock or quartz-schist brought up by a series of sharp inverted folds. In the cliff on the north side of the path there is a very fine clear section some 200 yds. in length, which shows the plicated junction between the biotite- and quartz-schists.

The structure of Beinn Enaiglair is similar to that of Meall Doire Fàid, except that the northerly termination of the biotite-schist outlier is mainly due to a general change in the direction of the dip of the strata. About half a mile west from the top of Beinn Enaiglair a rather broad band of siliceous rock appears which seems to run for 250 yds. along the strike, or north-and-south. It is probably an infold of the quartz-schist before described, as occurring in the biotite-schist under Sgùrr Mòr. The lower portion of the biotite-schist is repeated north of Beinn Enaiglair by a considerable fault running E.S.E. which makes a marked feature. It is evident that, to the north of this hill, the series of sharp north-and-south folds is dying out. The dip in the underlying siliceous schists changes gradually from E.S.E. round to south and then to south-west, exactly as it does when we follow the beds up the Lael valley, and the occasional sharp north-and-south folds visible to the north of Beinn Enaiglair do not follow the general strike and do not seriously affect the general dip. They appear here to be something superimposed on the general structure exactly as in other localities. To the east of Beinn Enaiglair, however, the sharp north-and-south plications continue to a greater distance northward the farther east we go. At the eastern end of Diollaid a' Mhill Bhric we find the normal south-west dip gradually changing to west, so that the strike coincides with the direction of the sharp north-and-south folds, as it does on the conical hill called Iorguill (2862 ft.) to the south. The northerly strike appears in the valley of Allt Coir' an Leth-Choin to the south-east and on Beinn Dearg. W. G.

The axis of plication on Beinn Dearg is continued northwards through Meall nan Ceapraichean and Eididh nan Clach Geala, along which the beds are suddenly rucked up into sharp asymmetrical folds, one limb of the fold being nearly horizontal, while the other may be vertical or even slightly overfolded.

Another zone of extreme plication crosses the summit of Meall Dubh, three miles N.N.E. of Inverlael. The overfolding is here far more pronounced, and the limbs of the folds often appear to be lying horizontally and parallel to one another. The structure of the ground between these two lines is generally simple. The beds dip at uniformly gentle angles, in directions varying from east by south round to south by west. This appearance of regularity is, however, possibly deceptive, for even where the beds seem to be arranged in regular succession, the crests of flattened overfolds can sometimes be detected, and it is thus possible that only a small thickness of rock may be involved in the plications that cover a wide area.

Numerous thin veins of quartz and a few veins of pegmatite, both probably of segregative origin, have been found in these rocks. In the Allt na Lairige, near its junction with the Douchary River, and in the latter stream below the foot of Allt na Creige Duibhe, there are veins of quartz with pyroxene, which occurs in strings or amorphous masses in the quartz, and also in isolated idiomorphic crystals. A section of a specimen taken from Allt na Lairige (10122) is thus described by Dr. Flett: "A massive quartz-rock with long crystals of dark-green pyroxene (diopside), idiomorphic in transverse section, slightly dichroic but with a high extinction angle. The felspar proves to be albite, with a little of the oligoclase molecule."

L. W. H.

In the north-east corner of the map bands of garnetiferous muscovite-biotite-schist are largely developed on the eastern spur of Seana Bhraigh and round Loch a' Chadha Dheirg, but elsewhere the type of rock is a granulitic quartzose schist of the Moine Series with occasional bands of biotite-schist. Over Seana Bhraigh and the northern slopes of Gleann a' Chadha Dheirg the schists are inclined to the S.S.E. at angles of from 20° to 30°. South of Gleann a' Chadha Dheirg the dip becomes more easterly, and on Tomain Coinich—a hill about half a mile E.N.E. of Eididh nan Clach Geala—it is E.N.E. Over these districts the rocks seem to be arranged in isoclinal folds.

C. B. C.

AREA SOUTH OF THE FANNICH WATERSHED.

In the description of this area we shall begin with those rocks that resemble certain types of Lewisian Gneiss, and refer to the other groups in order on either side of the Fannich fold.

Group 𝔄. Acid Gneiss with Lewisian Types.—On the eastern limb of the Fannich fold the members of this group have been traced from the watershed on Sgùrr nan Clach Geala to Torran Ruadh, within half a mile of Loch Fannich. The best section of them along this belt is to be found at the head of Allt Leac a' Bhealaich, a stream that drains the southern slope of Sgùrr nan Clach Geala and joins Abhuinn Nid near the head of Loch Fannich. It lays bare a more or less continuous section for over half a mile. The strike of the rocks there is N.N.W., and the foliation planes are generally inclined to the E.N.E. The prominent type consists of quartz-biotite-gneiss with basic knots or lenticles of hornblende-rock or hornblende-schist. The gneiss is usually granulitic, especially near the margins of the belt. The two basic bands already described (p. 67) that come together to the west of Sgùrr nan Clach Geala appear near the head of this stream. Another section is exposed in a tributary of Allt Leac a' Bhealaich, that rises one-third of a mile west of the top of Sgùrr nan Each. Near the head of this burn pink and grey granulitic gneiss with basic lenticles appears, and between the stream and the margin of the belt of acid gneiss a band of epidiorite has been traced which merges in places into hornblende-schist.

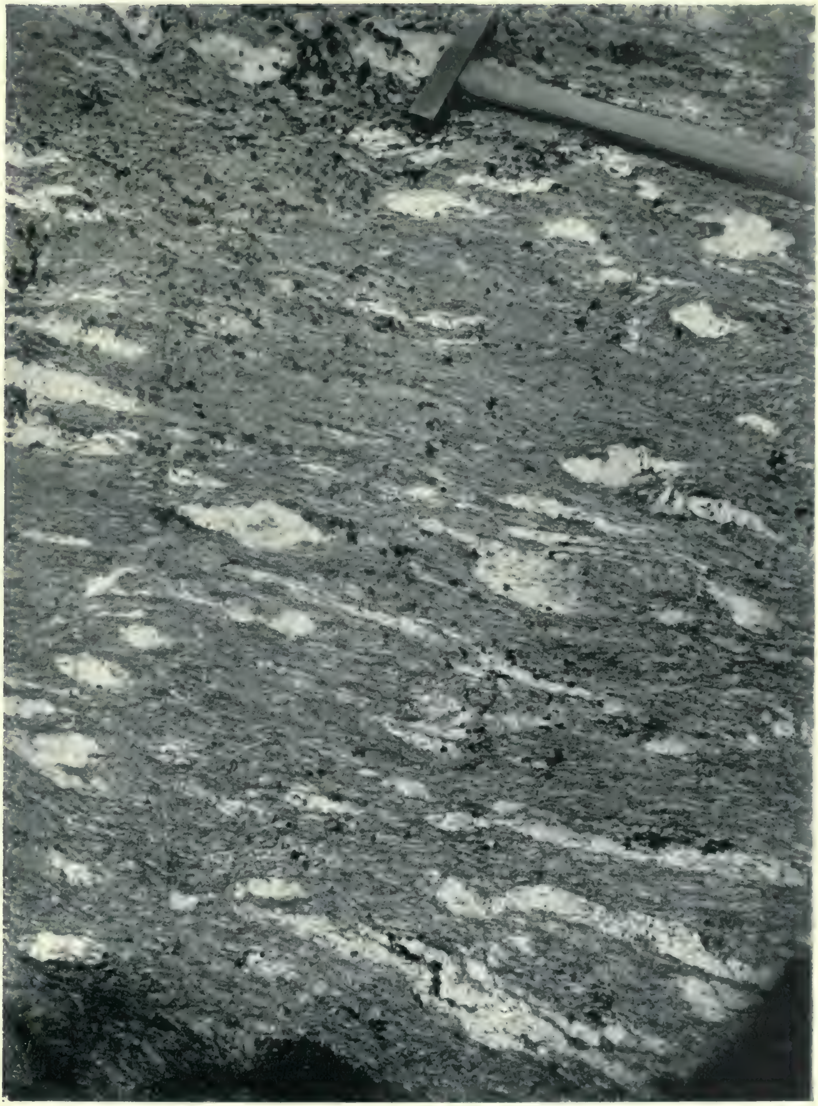
On the south-west slope of Sgùrr nan Clach Geala, at the eastern boundary, the acid gneiss rests on the muscovite-biotite-gneiss (group 1, Section A., Plate II.), both being inclined to the W.S.W. This westerly dip is continued in a long tongue of the acid group that runs southwards for a mile, east of Sgùrr nan Each. But along the main belt between that hill and Torran Ruadh, the prevalent inclination of the foliation planes is towards the east or E.N.E., where the flaser character of the acid group, indicating much differential movement of the constituents, is conspicuously developed.

Passing now to the outcrops of the acid gneiss on the south-west limb of the Fannich fold, we find that the members of this group reappear at the foot of a burn that enters Loch Fannich about three-quarters of a mile W.S.W. from Torran Ruadh and about a mile from the head of the loch. Here they are exposed for about 250 yds. in the stream with varying dips, but at the junction with the overlying muscovite-biotite-gneiss (group 1, Section B., Plate II.) they are inclined to the north-east and plunge beneath the latter group. They consist of grey and pink granulitic acid gneiss with knots of hornblende-rock about 3 ft. across. This outcrop is traceable for about a mile, in the form of a narrow belt from 50 to 200 yds. broad, along the south-west slope of Sàil Mhòr, about the 1250 ft. level. Their upper boundary is clearly defined as they rise from underneath the overlying cake of muscovite-biotite-gneiss, but their lower boundary is concealed by drift. Here, we find again a band of epidiorite merging into hornblende-schist, which has been followed for about a third of a mile. At one locality it cuts across the foliation of the acid gneiss, like the epidiorite dykes in the Lewisian Gneiss in the west of Ross-shire.

Owing to the covering of drift, peat and alluvium, no solid rock is visible at the Nest at the head of Loch Fannich nor in the lower part of Abhuinn Nid. Hence the boundary on the east side of the valley at the Nest is conjectural. But above the alluvial flat at the Nest the pink acid gneiss reappears in the channel of the Abhuinn Nid about a mile from the head of the loch. From this point the outcrop of the acid gneiss in the western part of the Fannich Forest is noteworthy. Owing to the gentle inclination of the rocks the members of the acid group there present a highly sinuous outcrop. They wind round the head of the valley of Abhuinn Nid to the ridge south of A' Chailleach, where they unite with the belt on the western slope of that mountain. Thence they extend southward along the crest of that ridge and sweep round both sides of An Sgùman to within half a mile of the Nest at the head of Loch Fannich (see map and Sections A. and B., Plate II.). Along this outcrop numerous stream sections show the lithological characters of the rocks. The evidence clearly indicates that the acid gneiss is underlain and overlain by the muscovite-biotite-gneiss (group 1). On the crest of the dividing ridge (An Sgùman) the overlying pelitic gneiss has been removed by denudation for nearly a mile, and the acid gneiss with its basic bands is laid bare in gentle undulations. Here as elsewhere in the Fannich Forest the dominant type is a pink or grey granulitic quartzose gneiss with a ferro-magnesian constituent often much decomposed. Bands of hornblende-gneiss are associated with the acid gneiss on the crest of An Sgùman, round the smaller outlier of pelitic gneiss about a mile and a half north-west of the head of Loch Fannich (See section B., Plate II.).

Group 1. *Muscovite-Biotite-Gneiss—Meall an t-Sìthe Rock.*—The pelitic gneiss of this group, as already indicated, both underlies and overlies the acid gneiss with Lewisian types. Attention will first be directed to the outcrops beneath the acid gneiss on either side of the Fannich fold. An excellent exposure occurs on the great crag on the eastern face of Sgùrr nan Clach Geala (Plate III.), and extends southwards to Sgùrr nan Each. In this escarpment, which lies on the eastern limb of the fold, the characteristic features of the rock are the abundance of garnets, the large plates of muscovite and biotite, and the presence in it of quartzo-felspathic material in knots and strings. The pegmatitic lenticles are arranged more or less parallel with the foliation of the schists, as shown in Plate III. The type varies considerably along the strike. Thus, the garnets become less numerous, the muscovite is hardly represented in places, and biotite is the dominant constituent, while the lenticles of quartzo-felspathic material disappear, and the rock then merges into a flaky biotite-schist. Bands of flaggy, siliceous, granulitic gneiss are intercalated with the members of this group.

In the great crag on the eastern face of Sgùrr nan Clach Geala the pelitic schist is seen to pass beneath the acid gneiss, the general dip of the foliation planes being to the W.S.W. at angles varying from 25° to 60° (group 1, Section A., Plate II.). Southwards in the direction of Loch Fannich it forms a belt from a quarter to half a mile in width. The extreme breadth of the belt where the angle of inclination is high is clearly due to folding. For example, on Sgùrr nan Each the pelitic gneiss appears on either side of the long tongue of



Garnetiferous Muscovite-Biotite-Gneiss with Lenticles of Pegmatite (Moine Series), Sgùrr nan Clach Geala, Fannich Forest.

acid gneiss, the former being traceable round the end of the tongue. Again, east of Torran Ruadh the flaggy, siliceous, granulitic gneiss, exposed in a stream in the midst of the muscovite-biotite-schist, is folded along axial planes running N.N.W. and S.S.E. It is not improbable that this narrow belt of flaggy, siliceous gneiss may be an infold of another zone (group 2) (see Sheet 92). South from Sgùrr nan Each the general dip of the pelitic schist is towards the E.N.E., that is, in a direction opposite to that on Sgùrr nan Clach Geala.

On the western limb of the fold the underlying outcrop of pelitic gneiss has been traced from the western slope of A' Chailleach, where this rock is exposed between the contour lines of 1750 and 2000 ft., along the south-western declivity of An Sgùman to the mouth of the Cabuie River and the head of Loch Fannich, thence up the valley of the Nest of Fannich to the corrie at the head of that valley. Along this sinuous outcrop the pelitic gneiss passes underneath the acid gneiss with basic lenticles (group 1, Sections A. and B., Plate II.). In the valley of the Abhuinn Nid there appears to be a slight anticlinal roll of these two rock groups, for on referring to the map it will be seen that the dip swings round in accordance with the outcrop of the boundary line between them. It is noteworthy that along the outcrop on An Sgùman and in the exposures near the mouth of the Cabuie River the lenticles of quartzo-felspathic materials are hardly represented in the pelitic gneiss. In places they disappear altogether, and the rock becomes a flaky garnetiferous muscovite-biotite-schist.

The mass of muscovite-biotite-schist that overlies the acid gneiss with basic lenticles covers a large area to the south of the Fannich watershed (group 1, Section A., Plate II.). It extends from A' Chailleach and Sgùrr Breac south-eastwards by Sàil Mhòr to the shore of Loch Fannich—a distance of four miles. It there occupies the centre of the apparent synclinal fold of the acid gneiss. An excellent cross-section is exposed in the stream—Allt Leac a' Bhealaich—which joins Abhuinn Nid half a mile above Loch Fannich. Here the rock presents lithological characters similar to those already described, except in one particular, that the quartzo-felspathic lenticles are not so abundant as in the great escarpment on the east face of Sgùrr nan Clach Geala. Thin pegmatites from 1 to 2 ft. thick with small prisms of tourmaline have been observed in this section. On the south-west slope of Sgùrr Breac and in the lower part of Allt Leac a' Bhealaich the general dip of the foliation planes is towards the north-east at angles varying from 15° to 45°. But in Sàil Mhòr and along the eastern margin of the overlying mass, they are highly inclined, folded, and contorted.

Two small outliers of the overlying mass of garnetiferous gneiss (group 1, Section B., Plate II.) occur on An Sgùman, where they rest on the narrow denuded plateau of the acid and basic gneiss (group 𝔄) already described. Such evidence furnishes clear proof of the denudation of the rock groups in this recumbent fold in the western part of the Fannich Forest. For the Abhuinn Nid in the Nest of Fannich has cut through the overlying mass of group 1, through the sheet of acid gneiss, down to the underlying muscovite-biotite-schist (group 1, Section B., Plate II.).

In the sequel (Chapter VIII.) reference will be made to the occurrence of lenticular bands of garnetiferous hornblende-rock in the muscovite-biotite-schist.

On the south side of the Fannich watershed no trace of a conglomerate has been detected at the margin of the pelitic gneiss (group 1) along its line of junction with the acid gneiss (group 𝔄). The marked linear foliation and striping of the acid gneiss at and near the boundary line between the two rock groups implies considerable differential movement of the constituents. Hence it may be inferred that the original relation between these two groups has been effaced by this movement. Nevertheless there can be little doubt that the underlying and overlying masses of garnetiferous gneiss are portions of one and the same sheet.

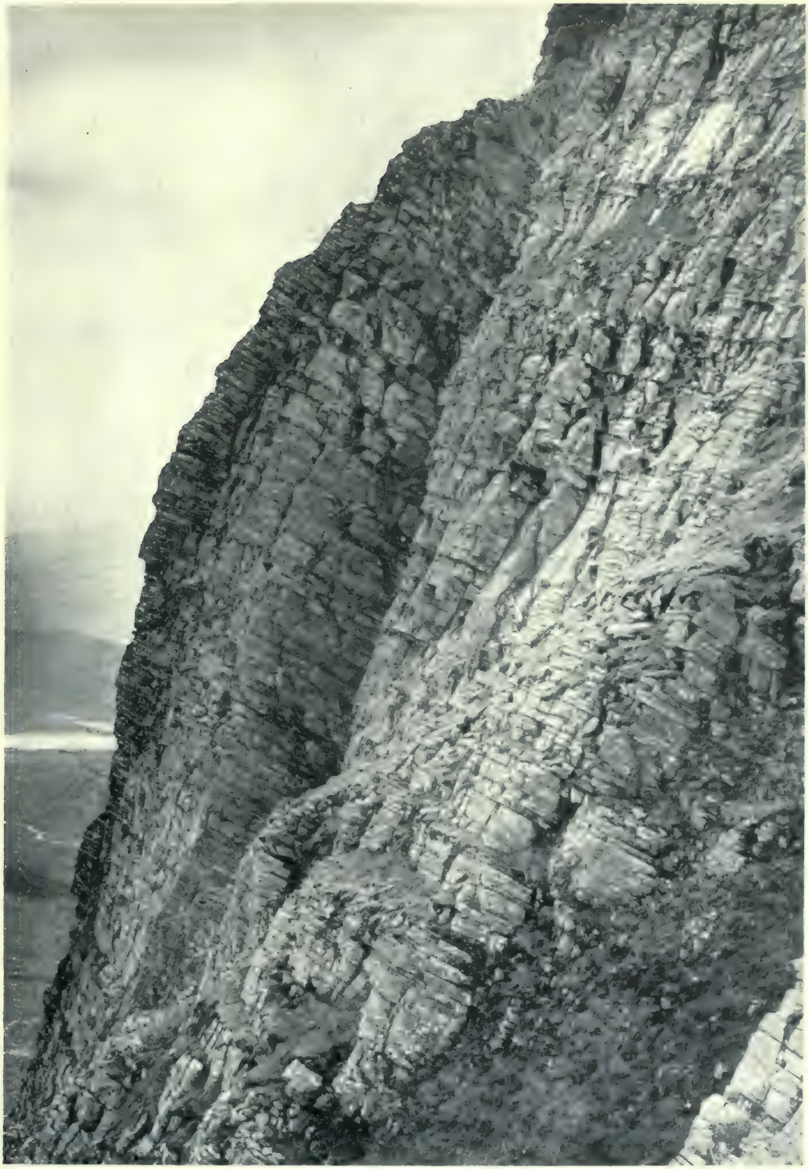
Group 2. *Meall a' Chrasgaidh Siliceous Schists.*—South of the Fannich watershed the members of this group consist of flaggy, granulitic, quartzose schists in marked contrast with the garnetiferous gneiss just described. The beds as a whole are highly siliceous, but in most of the bands some minute biotite is present and occasionally muscovite. The divisional planes are coated with mica. Sometimes thin layers of mica-schist alternate with the siliceous flags. The normal phase of this group may be taken as a typical granulitic quartzose Moine Schist.

The best exposure occurs on the eastern limb of the Fannich fold, on the east slope of Sgùrr nan Clach Geala (Plate IV.), where they dip to the west and W.S.W. at angles varying from 40° to 60°, and plunge underneath the pelitic gneiss (group 1, Section A., Plate II.). From that point southwards they can be traced as a narrow belt about a quarter of a mile broad to Allt a' Choire Mhòir, where they become vertical, and eventually dip to the east and east-north-east at about 70° (see group 2, Section B., Plate II.).

On the western limb of the fold these flaggy siliceous schists appear on the col between A' Chailleach and Meallan Chuaich, where they rise from below the garnetiferous muscovite-biotite-gneiss (group 1) and dip to the east at an angle of 10°. The boundary line between these two groups is there well defined. They have been traced south-eastwards along the south slope of An Sgùman to a point on the Cabuie River about a mile west from Loch Fannich.

Group 3. *Sgùrr Mòr Biotite-Schist.*—On the eastern limb of the fold this group has been traced from the watershed to the shore of Loch Fannich. Consisting mainly of biotite-schist with occasional small garnets and thin intercalations of siliceous schist, the strata are displayed on the col at the head of Allt a' Choire Mhòir, on Sgùrr Mòr, and on Druim Rèidh. The prominent band of quartz-schist in the midst of this group has been followed from the corrie on the east side of Sgùrr Mòr, across the watershed, to near the foot of Allt a' Choire Bhig. Although the mica-schists are highly puckered, the sections on the cliffs round the west side of Sgùrr Mòr show that the rocks are generally inclined to the west, while about three miles to the south they are either vertical or highly inclined to the east or west. Along the eastern margin of this belt on the watershed the biotite-schist is inclined to the east-south-east, thus indicating an inversion of the strata (see Section A., Plate II.).

The bands of zoisite-schist, detected by Mr. Gunn in this group, on the north side of the Fannich watershed, have been observed at



Flaggy Siliceous Schists (Meall a' Chrasgaidh group), Moine Series, east face of Sgùrr nan Clach Geala, Fannich Forest.

various localities, along the outcrop between Sgùrr Mòr and Loch Fannich. They occur in the biotite-schist in seams from 1 to 3 ins thick, which, on weathered surfaces, show prisms of zoisite about a quarter of an inch in length. Sometimes, where the schists are highly puckered, the zoisite-rocks appear as small lenticles. Specimens collected from this region were sliced and examined under the microscope by Dr. Teall, who furnished descriptions, two of which are given below:—

(8203.) West slope of Sgùrr Mòr Fannich. Light grey, fine-grained granulite with conspicuous prisms of zoisite about ¼ inch in length on the flat surface of the specimen. Under the microscope appear garnet (colourless in thin section), zoisite and quartz, with biotite, chlorite and sphene as accessories. Undoubtedly allied to Mr. Gunn's rock, but without the hornblende; quartz-garnet-zoisite-granulite, or, in short, zoisite-granulite.

(8205.) Same locality. Similar to the above, but darker, and containing large garnets. Under the microscope are seen garnet, zoisite, quartz, plagioclase, hornblende and biotite. Opaque particles as in 8204. The minerals are not uniformly distributed. The hornblende is usually in association with the felspar, and the zoisite with the quartz and garnet. The rock is more or less banded; garnet-zoisite-amphibolite.

Three small outliers of biotite-schist, which are correlated with this group, occur in the eastern part of the Fannich range, to which special reference will be made in the description of group 4.

On the western limb of the Fannich fold a narrow band of biotite-schist with small garnets appears on the col to the west of A' Chailleach, and on the north portion of the hill named Meallan Chuaich, where it rises from underneath the Meall a' Chrasgaidh siliceous schists (group 2) with a dip to the east-north-east (Section A., Plate II.). This band has been correlated with the Sgùrr Mòr biotite-schist, but as it occurs here in a highly attenuated form it may represent part only of that group. A glance at the map will show that it has been mapped along the south-west slope of An Sgùman to the Cabuie River, where it is exposed about a mile and a quarter above Loch Fannich. It is probable that certain ill-defined bands of biotite-schist that have not been traced to the west of this outcrop on either side of the Cabuie River may also represent part of this group. This view is strengthened by the occurrence of seams of zoisite-amphibolite rock on the plateau to the west of Beinn nan Ramh.

Group 4. *Flaggy Granulitic Schists and Gneisses.*—On the west limb of the Fannich fold the members of this group occupy the ground between the Moine thrust and the outcrop of the Sgùrr Mòr biotite-schist on Meallan Chuaich. At certain localities near the Moine thrust, as, for instance, on the ridge east of Loch a' Mheallain Odhair, there is a development of green and streaky mylonites, the origin of which is difficult to determine. Some of these rocks may be due to the deformation of bands of Lewisian Gneiss, others to the crushing of Torridon Grit, and, in one instance (4708), the rock may not improbably be a member of the Moine Series, the structure of which has been modified by the post-Cambrian movements. It is worthy of note, however, that the fine-grained, greenish-grey schist that immediately overlies the Moine thrust-plane at the south end of the Loch an Nid crag is a typical Moine Schist. It is composed of a granulitic aggregate of quartz and felspar, with scales of white mica and "eyes" of felspar.

The members of this group are displayed on Beinn Bheag and An Groban, west from A' Chailleach (Section A., Plate II.), where they consist of fine-grained granulitic quartzose schists with occasional thin intercalations of mica-schist. The flaggy and fissile character of the series is here well pronounced. Lithologically they indicate a low grade of metamorphism compared with their representatives on the eastern limb of the fold north of Loch Fannich. The general dip of the strata between Beinn Bheag and the west slope of A' Chailleach is easterly, so that they plunge below the groups already described which enter into the structure of the Fannich fold. But there are indications of overfolding and reduplication of the strata, and the steady ascending sequence may thus be deceptive.

When these rocks reappear on the eastern limb of the fold they present a higher grade of metamorphism. The flaggy granulitic character is still persistent, but the rocks are more highly crystalline, and biotite as a rule is more abundant. Along their line of junction with the Sgùrr Mòr biotite-schists on the Fannich watershed there is evidence of sharp plication and inversion. On Creachan Rairigidh, the lofty ridge between Sgùrr Mòr and Meall Gorm, the quartzose granulites (group 4) have been made to overlie the Sgùrr Mòr biotite-schists. The system of Z-shaped folding characteristic of this inversion is well seen on the cliff at the head of Allt a' Choire Bhig. This inversion is more or less in the line of the axis of plication and overfolding already described by Mr. Gunn as running northwards through the Braemore Forrest along the eastern slopes of Meall Doire Fàid and Beinn Enaiglair.

Along the eastern part of the Fannich range, from Creachan Rairigidh by An Coileachan to the mouth of Loch Fannich, the members of group 4 are arranged in an apparent synclinal fold, with the axis of which the crest of the range more or less coincides, in a south-east-by-south direction. On both limbs of this fold the rocks dip at gentle angles of 12° to 20°, till in the eastern limit of the chain they become vertical or highly inclined to the west. The westerly dip of the flaggy quartz-biotite-schists and gneisses is well displayed in Garbh Choire Mòr about a mile to the north of the mouth of Loch Fannich (group 4, Sections A. and B., Plate II.).

An interesting feature in the structure of the eastern part of the Fannich range is the occurrence of three outliers of biotite-schist: (1) on the south end of Creachan Rairigidh; (2) on An Coileachan; (3) on a hill about half a mile to the north of the mouth of Loch Fannich. They form thin cakes composed of flaky and granulitic biotite-schist resting on the gently-inclined quartzose granulites. The largest outlier, about half a mile in diameter, occurs at the first locality, where the schists dip to the S.S.W. at 10°, and contain a band rich in zoisite. Another zoisite-bearing band has been found in the outlier near the mouth of Loch Fannich. In view of the lithological characters of the rocks in these outliers, they have been correlated with the Sgùrr Mòr biotite-schist (group 4, Section A., Plate II.).

No sills or bands of hornblende-schist have as yet been detected in the thick group of siliceous schists or gneiss (group 4) in the eastern part of the Fannich range. Pegmatites are of rare occurrence. A thin vein of microcline-pegmatite was observed in the outlier of biotite-schist on the top of Meall Gorm, and another in the quartzose granulitic schists in Coire Riabhach to the south of that hill. Dr. Teall, who examined specimens collected from these veins, states, regarding the latter, that "it is not intended to imply that soda-felspars are absent from those pegmatites, but only that microcline is present. They are not purely albite-pegmatites, such as occur in segregations in the Cowal district and in South Devon."

Summary.—From the evidence now adduced regarding the arrangement of the rock groups in the area to the north of Loch Fannich, it is clear that they form a great recumbent fold with an amplitude of several miles (see sections A. and B. in Plate II.). The acid gneiss with Lewisian types and the various groups of crystalline schists of the Moine Series have been traced more or less continuously round this fold. Between the Moine thrust and the western limit of the Fannich group the schists dip eastwards. In the western portion of the Fannich range the rocks are almost flat or inclined at low angles; in the centre they are highly inclined, vertical, or inverted; in the eastern part they are nearly horizontal or dip at moderate angles. It is obvious that the structure is much more complicated than that of a normal synclinal fold. The relations which the rock groups bear to each other along the line of Section A. in Plate II. are suggestive of fan-structure, though this interpretation cannot be definitely proved by evidence obtainable within the Fannich range.

Further, it may be noted that no direct evidence has been obtained in the Fannich region of an unconformability between the muscovite-biotite-schist of the Moine Series (group 1 in Sections A. and B., Plate II.) and the acid gneiss with Lewisian types (group 𝔄). If the interpretation of the evidence in the region to the south is accepted (Sheet 82), then, presumably, the members of the Moine Series are here younger than the acid gneiss with basic rocks. It would also follow that the various subdivisions of the Moine Series are inverted, the garnetiferous pelitic gneiss (group 1) being the oldest and the flaggy quartz-biotite-schists (group 4) being the youngest in the Fannich sequence. J. H.

Between the eastern limits of the Fannich range and the eastern margin of the map the rocks are remarkably uniform in character and structure. They consist of flaggy quartzose gneiss alternating with dark-coloured biotite-schists, in vertical beds, having a general north-and-south strike. On the whole, the quartzose gneiss is predominant, but a well-marked zone of biotite-schist, with but few bands of quartzose schist, has been traced for about a distance of five miles from the south slope of Beinn Liath Mhòr a' Ghiubhais Lì by Beinn Dearg to the plateau beyond Càrn na Bèiste in the south-east corner of the map. This biotite-schist zone is closely similar to the Sgùrr Mòr schist (group 3 in Section A., Plate II.), and most probably is a mass of the same rock folded into the quartzose series to a depth of about 1400 ft. on a north-and-south axis. It is intensely puckered, and is full of twisted lenticles of vein-quartz. It is well seen on the top of Càrn na Bèiste, a mile E.S.E. from the lower end of Loch Fannich, where it attains a maximum breadth of half a mile. The crag at the summit of that hill is formed by a prominent quartzose sub-zone, which stands up above the softer features of biotite-schist on either side.

On referring to the map, it will be seen that two narrow bands of biotite-schist occur from a quarter to half a mile west of that on Beinn Dearg. They lie close to the stream named Allt a' Choin Idhir—a tributary of the Grudie River that issues from Loch Fannich—and may also be repetitions of the Sgùrr Mòr schist. In the more westerly of these two outcrops the zoisite-amphibolite-rock was found at a point about 500 yds. north from the foot of that stream.

The quartzose gneiss on the east side of the broad band of biotite-schist on Beinn Dearg and Càrn na Bèiste resembles that in the great corrie at the eastern end of the Fannich range (Garbh Choire Mòr) in general characters, but is somewhat more massive, and in places contains thin folia of pink felspar. It rises into the prominent crag that forms the eastern shoulder of Càrn na Bèiste.

Passing now to the ground lying between the Cabuie River (Abhuinn a' Chadh' Bhuidhe) and Srath Chrombuill, we find the southern prolongation of the coarse, flaky, garnetiferous gneiss (group 1 of the Fannich sequence) on the top and eastern slopes of Beinn nan Ramh (2333 ft.). As in the Fannich region, it here consists, in its most typical form, of folia of muscovite and biotite, is full of dark-red garnets, and contains lenticles of pegmatite from a quarter of an inch to an inch in thickness. But it presents considerable variations in character. Some of its finer-grained portions contain little or no pegmatite, and cannot be distinguished in hand-specimens from ordinary bands of mica-schist in the Moine Series. Others display the pegmatite arranged in sub-parallel lenticles, while a third type presents muscovite developed almost to the exclusion of biotite. The pegmatites of this rock sometimes measure several feet in thickness. A few of the larger veins contain a beautiful rock made up of large plates of muscovite up to 3 ins. in diameter, set in a quartzose matrix, crowded with small stumpy prisms of black tourmaline. Some of the tourmaline crystals attain a length of 4 or 5 ins.

Closely associated with the flaky gneiss is a granitoid gneiss made up of coarse white quartzo-felspathic layers with intensely contorted micaceous folia. It is well seen on the eastern slopes of Beinn nan Ramh, where it is folded up with the flaky gneiss on a general north-west and south-east axis. Farther west several distinct outcrops of a similar rock occur, some of which pass into a fine-grained quartzose gneiss with thin folia and "eyes" of felspar resembling the acid gneiss (group 𝔄) of the Fannich range. The basic portions of the granitoid gneiss usually appear as hornblende-schist dykes, traceable for short distances, and folded with the main mass of the rock. It is uncertain whether this granitoid gneiss with its basic bands of hornblende-schist represents the acid gneiss with Lewisian types of the Fannich sequence. T. I. P.

Attention will now be directed to the area lying to the south of Srath Chrombuill and to the south of the eastern part of Loch Fannich. Immediately above the Moine thrust-plane at the mouth of the Leckie Burn and near the Heights of Kinlochewe, we find a belt of green schist or mylonised rock from 300 to 500 ft. in thickness, which includes both pelitic and psammitic representatives of the Moine Series. At this locality the outcrop of the Moine thrust has been shifted for three-quarters of a mile to near the foot of Gleann Tanagaidh by an E.N.E. and W.S.W. fault. This zone is succeeded by flaggy, fine-grained quartz-granulites with white mica. The flags are separated by partings of micaceous material, chiefly white mica and chlorite, but occasional intercalations of mica-schist occur. Eastwards in the area traversed by Allt na Doire-giubhais and the small burn about half a mile to the east of that stream, the pelitic mica-schists are as abundant as the quartz-granulites. Up to this point the schists are traversed only by veins of quartz, which are usually thin and granulitised.

Farther east there is a marked increase in the grade of metamorphism. The constituents of the granulites become larger, and biotite becomes more abundant both in the pelitic and psammitic schists. In Allt a' Chlaiginn—a stream south from Strathcromble, a cottage now in ruins—flaggy quartz-granulites alternate with biotite-granulites and biotite-schists in about equal proportions. It is highly probable that the belt of these schists, exposed in the lower reaches of this stream, represent the Sgùrr Mòr biotite-schist (group 3 of the Fannich sequence). This pelitic zone is succeeded towards the east by flaggy quartz-granulites, which may be the southern prolongation of the Meall a' Chrasgaidh quartz-schist (group 2) of the Fannich succession.

Next in order we find a prominent belt of muscovite-biotite-schist which is well displayed on Fionn Bheinn (3060 ft.) and stretches eastwards to Loch na Mòine Mòr. It presents the characteristic features of the Meall an t-Sìthe gneiss (group 1) of the Fannich sequence, with lenticles of quartzo-felspathic material and abundant garnets, and is doubtless the southern continuation of that group. With this type are associated flaggy mica-schists and minor intercalations of quartz-granulite. On the eastern slopes of Fionn Bheinn occur lenticular knots and bands of garnetiferous hornblende-rock, which probably represent folded and disrupted portions of sills or dykes of basic rock intrusive in the original sediments.

The mass of pelitic gneiss round Fionn Bheinn is followed eastwards by a belt of quartz-granulite, which may be a repetition of the Meall a' Chrasgaidh quartz-schist (group 2), with a second outcrop of the muscovite-biotite-schist east of Loch na Mòine Mòr. East of the latter belt the rocks are much concealed by peat and drift. The exposures reveal an alternation of quartz-granulites and bands of biotite-schist, probably representing groups 3 and 4 of the Fannich succession.

Regarding the tectonics of the area lying to the south of Srath Chrombuill and Loch Fannich, it may be remarked that the schists east of the Moine thrust-plane appear to dip to the east-south-east or east at comparatively low angles; but this is evidently due to flat overfolding, which can be observed in numerous sections on a small scale, where the overfolds are only a few feet or yards in amplitude. The mapping of a wider area, however, makes it clear that flat or lowly inclined overfolds of great amplitude also occur. For the garnetiferous muscovite-biotite-gneiss (group 1 of the Fannich sequence) has been traced from Beinn Dronaig in Sheet 82 to the Fannich Mountains in Sheet 92. In the former region it occupies the crest of a recumbent anticlinal fold with a core of Lewisian Gneiss. It is the same band of pelitic gneiss which, in Glenelg and at Attadale, rests upon the Lewisian Gneiss. Again, within a mile from the south edge of Sheet 92, near Achnashean, there is a small exposure of Lewisian Gneiss in the midst of this band, while in the Fannich Mountains the double outcrop of garnetiferous gneiss (group 1) has an intervening belt of acid gneiss with Lewisian types. It follows that the siliceous and micaceous schists that lie between the Moine thrust-plane and Fionn Bheinn must occupy a broad synclinal fold, which is a continuation northwards of the Strathcarron syncline. In Fionn Bheinn the pitch of the Fannich fold has evidently carried the acid gneiss below the existing level of denudation, although the Fannich structure is doubtless repeated in the area south of Loch Fannich.

The belt of siliceous granulite, which at Loch na Mòine Mòr separates the two broad masses of pelitic gneiss south of Loch Fannich, may represent a recumbent downfold of the Meall a' Chrasgaidh quartz-schist (group 2). The tops of Meallan Odhar and Càrn Daraich south of Loch Fannich are capped by alternations of biotite-schist and quartz-schist, while to the east, on An Cabar, the back-fold or recumbent anticline in the eastern part of the Fannich range is still traceable.

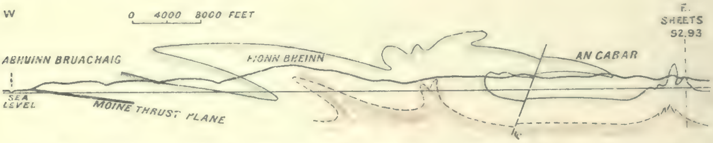


FIG. 6.—Diagrammatic Section from near the Heights of Kinlochewe by Fionn Bheinn and An Cabar to the eastern edge of Sheet 92.

The accompanying diagrammatic section (Fig. 6) expresses the probable nature of these folds. The thick continuous line represents the existing surface contour of the ground relatively to the sea-level on the scale of one inch to four miles. The interrupted line indicates the old floor of Lewisian Gneiss upon which the Moine Schists rest, while the thin continuous line illustrates the divisional plane between the Sgùrr Mòr biotite-schist (group 3) and the granulitic quartzose mica-schists (group 4) of the Fannich sequence. These two groups have not been separated from each other by a line on the map in the areas to the south of Loch Fannich and the west of Fionn Bheinn.

B. N. P.

CHAPTER VIII.

GARNET-HORNBLENDE-ROCKS IN MOINE SERIES, AND DYKES OF MICA-TRAP AND LAMPROPHYRE.

Garnet-Hornblende-Rocks.—In the pelitic gneiss of the Moine Series (group 1 of the Fannich sequence) occasional bosses and sills of garnet-hornblende-rock are to be found, which are evidently intrusive. They are often crowded with garnets, and hornblende is the chief constituent of the rock. They have not been traced for any great distance. Along the watershed of the Meall an t-Sìthe ridge north-west from Loch a' Bhraoin these bands may be seen to cross the foliation of the pelitic gneiss. A specimen collected from the western part of this ridge on Meall Dubh is thus described by Dr. Teall :—

(4702.) A dark, coarse-grained massive rock, largely composed of garnet and hornblende, which shows under the microscope garnet, hornblende, biotite, and quartz, but no felspar. Sphene occurs as an accessory.

In the Fannich range these rocks have also been detected in the garnetiferous-muscovite-biotite schist near Loch na Sàlach east of Sàil Mhòr, in Allt Leac a' Bhealaich, on the south slope of Sgùrr Breac, and in one of the outliers of this zone on An Sgùman. Beyond Loch Fannich they have been observed in the same zone on Fionn Bheinn. W. G., B. N. P., J. H.

The flaky gneiss on Beinn nan Ramh, south of Cabuie, contains lenticular masses of garnet-hornblende-rock. Though sometimes traceable as dykes for short distances, they usually take the form of irregular rounded masses of amphibolite. A boulder from one of them, found on the east side of that hill, contains a vein with crystals of black hornblende three-quarters of an inch long. T. I. P.

Mica-Traps and Lamprophyres.—In the area of crystalline schists east of the Moine thrust a few dykes of lamprophyre have been observed. Of these, the most persistent example is one that has been traced for several miles along the plateau to the south of the lower end of Loch Fannich. At one locality, three-quarters of a mile west from the top of An Cabar, it measures 18 ft. in breadth. A second instance has been noted near the foot of the burn that drains Loch na Mòine Mòr south of Loch Fannich and about two miles south-east from the head of that loch. A third occurs in one of the tributaries of Abhuinn Nid in the corrie at the head of the Nest of Fannich.

Two examples have been found on the north side of the Fannich watershed, one in the lower part of the burn that runs from Loch Toll an Lochain into Loch a' Bhraoin, the other in Allt Daimh Mòr—a stream to the south-west of Meall a' Chrasgaidh. The dyke in the former burn is fine-grained, and only 2 ft. wide. Though in places it comes up vertically as a dyke, in others it behaves more like a sill. The rock in Allt Daimh Mòr is several yards in width, is coarser in grain and decidedly pink in colour. Traces of a red lamprophyre found in two places at the north end of Druim Ruadh, probably belong to a sill or dyke similar in character to those already referred to.

Dr. Flett reports that all the lamprophyres which have been microscopically examined from this sheet belong to the minette-vogesite series, and no representatives of the camptonite-monchiquite association are known to occur in it, though such are found in Sheet 82 to the south.

On the west side of the Moine thrust several mica-trap dykes have been recorded.

The most northerly example is seen cutting the Torridonian strata rather less than half a mile slightly east of south of Sgùrr Fiòna, An Teallach, in a deep, narrow nick striking W.S.W. It is only 2 or 3 ft. thick and much decomposed. Another deep gorge just on the south side, is possibly also occupied by a similar dyke. It continues westwards nearly to Loch na Sheallag, about a mile distant. On the east side of Loch Toll an Lochain, a conspicuous hollow, almost in the line of the two gorges referred to, continues E.N.E. more than two miles, as far as the Cambrian quartzite, where it gives place to a fault-scar facing north. No dyke has been noticed along this fault, but the ground is in places very obscure.

In a little burn about a mile south of Carnmore, a small dyke of mica-trap, with large scales of biotite, strikes in a N.N.W. direction through the Lewisian Gneiss. It is generally about 2 ft. thick, but occasionally disappears entirely for a short space.

The most southerly dyke of mica-trap makes a conspicuous hollow in the Torridonian strata on the east side of the Bridge of Grudie, south of Loch Maree. It has been traced westwards for about a mile, and shows in one place a thickness of 4 ft.

In the valley of Amhainn Loch an Nid, and about two-thirds of a mile north from that loch, the unthrust Cambrian quartzites are traversed by a dyke of mica-trap with plates of biotite. It trends W.N.W., and has been traced for about 100 yds.

W. G., C. T. C., B. N. P., J. H.

CHAPTER IX.

MESOZOIC ROCKS.

TRIAS.

THE Trias is represented in a very small area, probably less than 30 acres in extent, at the extreme north-western corner of the map. It forms part of a strip of Mesozoic rocks which have been let down between the harder Torridonian strata by two great faults, striking N.N.E., and have thus been protected from denudation.*

The only exposure is on and close to the shore, and consists of white and mottled sandstones with reddish clays and shales and some bands of conglomerate, dipping south or south-west, at angles between 6° and 10°. The east end of the exposure shows about 30 or 40 ft. of mottled clay with bands of white sandstone. From the disposition of the strata in the adjoining one-inch maps it is clear that these exposures belong to the highest beds of the formation: the lower beds are mainly composed of conglomerates made up to a large extent of fragments of Cambrian Limestone, Cambrian Quartzite, and Moine Schist. The whole series is somewhat calcareous. Lumps of concretionary limestone are not uncommon, and all the sandstones weather with rough carious surfaces. Prof. Judd † considers that the total thickness of the formation in this district exceeds 1000 ft., but only a small part of this comes into the map being described.

The numerous pieces of Cambrian Quartzite and Limestone in the conglomerate indicate that in the Triassic period these beds probably extended much farther west and made more extensive outcrops than they do now. The nearest Cambrian rocks *in situ* are now more than a dozen miles distant, with the exception of a few small crushed fragments which have been dragged down into the large fault at Beinn Dearg Bad Chailleach, about three and a half miles south from the Triassic conglomerate. It is, however, to be noted that where the base of the Trias is seen, a mile N.N.W. of the north-west corner of the map, it is resting unconformably, not on Cambrian beds, but on Torridonian strata belonging to the highest or Aultbea group.‡

* Prof. Judd, "The Secondary Rocks of Scotland." Third Paper. "The Strata of the Western Coast and Islands," *Quart. Jour. Geol. Soc.*, vol. xxxiv. (1878), p. 670. Macculloch and Prof. Nicol also referred to these strata, the former in his "Western Isles of Scotland," vol. ii. (1819), p. 99, and Plate xxxii. of vol. iii., and the latter in his paper "On the Newer Red Sandstone and on some other Geological Phenomena near Gruinard, in Ross-shire," *Quart. Jour. Geol. Soc.*, vol. xiv. (1858), p 167.

† *Op. cit* p. 680.

‡ A picture of a natural section in which the unconformability is very distinct is given by Prof. Nicol. *Op. cit.* p. 168.

LIAS.

The Lias, it is believed, conformably succeeds the Trias just described, in a south-east direction, and forms most of the hamlet of Sand In this one-inch map it probably occupies a somewhat larger area than the Trias, but it does not extend to the shore, and is therefore not well exposed.

A blue argillaceous limestone has been dug out of the ground for use in an old limekiln about 60 yds. south-west of the coast road, and is supposed to be very near the base of the formation. Rather more than half a mile slightly west of south of the north-west corner of the map, and thus a little within the adjoining one-inch map 91, another limekiln is seen, and an old limestone quarry, showing 3 or 4 ft. of light-coloured sandy limestone. In another small tract lying between these two kilns, but nearer the latter than the former, a blue shelly limestone is said to be close to the surface.

The only fossil determined from the Lias of Sand is *Gryphæa arcuata*, Lam., but the exact locality from which the specimen was collected is not known.

The Liassic strata continue, however, under drift for some miles south-west, to the north-east shore of Loch Ewe. Numerous blocks of Liassic limestone are found on this shore near Aultbea, and they doubtless represent beds which occur *in situ* near at hand. From these blocks a number of fossils have been collected by the Geological Survey, as the following list shows:—

Lucina sp.
Modiola scalprum J. Sow.
  „ *hillana* J. Sow.
Pinna sp.
Pteria (*Oxytoma*) *inequivalvis* (J. Sow.).
Gervillia sp.
Lima (*Plagiostoma*) *pectinoides* (J. Sow.).
  „ „ *hettangiensis* Terq.
Pecten (*Syncyclonema*) *liasinus* Nyst.
Ostrea liassica Strickl.
Pleuromya costata (Young and Bird).
Gasteropods.

The list of fossils collected by Prof. Judd in the same locality is given by him as follows:—

Ostrea irregularis, Münst.; *Gryphæa arcuata*, Lam.; *Pinna Hartmanni*, Ziet. sp; *Lima succincta*, Schloth. sp; *Lima gigantea*, Sow.; and fragments of Echinodermata.*

W. G.

---

* *Op. cit.* p. 704.

CHAPTER X.

FAULTS.

The pre-Torridonian lines of disruption and deformation, and the great thrusts which characterised the post-Cambrian movements, have already been described in Chapters III. and VI. respectively. Attention will now be directed to other lines of fracture which occur within the area included in the map. Among these, the most important one is the Loch Maree fault, which coincides in part with a pre-Torridonian crush line. The prominent features of this disruption in post-Torridon time are the horizontal displacement of the geological structure lines near Loch Maree and the brecciation of the rocks in the Glen Docherty valley. It has been traced far beyond the limits of the present map. Entering the loch at its head, it runs near the northern shore to a point north from Eilean Subhainn, where it leaves the lake and runs along the base of the precipitous slope behind Ardlair. Beyond that mansion house it once more enters the lake, passes down the River Ewe to within a mile of Poolewe, and extends north-westwards to near Camas Mòr, east of the Rudh' Ré. In the opposite direction it has been traced up Glen Docherty and across country by Ledgown to Loch Beannachan in the basin of the River Meig.

A comparison of the structures on either side of the valley below Glen Docherty (Sheet 82) shows the horizontal displacement produced by the Loch Maree fault. It will be seen (1) that the Fasagh dislocation has been shifted three miles to the west to Glen Grudie; (2) that the outcrop of the undisturbed quartzite on Beinn a' Mhùinidh has been carried westwards to a point beyond Rhu Noa pier on Loch Maree; and (3) that the outcrop of the Moine thrust-plane has been also borne westward from the hill-slope east of Bruachaig (Sheet 82) to the valley at the Kinlochewe Hotel. In like manner the axes of the compound syncline between Beinn a' Mhùinidh and Abhuinn Bruachaig have been moved farther west on the south side of the displacement to Meall a' Ghiubhais and the ridge south-west of Taagan. Accompanying this horizontal displacement there has been a vertical downthrow of about 1000 ft. towards the north.

The Fasagh fault is also an important structural feature. Its downthrow is to the east and south-east, and the displacement of the strata produced by it may best be studied along its course from the head of Loch Maree to the pass between Mullach Coire Mhic Fhearchair and Beinn Bheag. In Gleann Bianasdail this dislocation lets down the Cambrian Quartzites and Torridon Sandstone on the east side of the valley against the inlier of hornblende-schist and overlying Torridon Sandstone on the west side. Skirting the east end of Lochan Fada it trends north-eastwards to Loch a' Bhraoin, and, as already indicated, it shifts the outcrops of the undisturbed Cambrian strata and overlying thrust masses for some distance to the west.

The fault running in a N.N.E. direction which bounds the Liassic and Triassic rocks at Sand has a downthrow to the west of 1000 ft. or more. It is visible on the shore, where it may be seen to hade westward at an angle of 60°, and a reef of brecciated Torridon Sandstone runs out to sea on the east side. To the southward for a long distance the upthrown Torridon Sandstone forms a good feature. This fault is later in date than the Lias, for the Liassic strata are displaced by it. Farther westward on the coast are two faults parallel to this, which throw the Trias, and it is probable that all three belong to the same period.

In its general direction the First Coast fracture is like the Sand fault, but its course is more irregular. It has a very large downthrow to the west, the higher Torridonian strata on that side abutting against the lowest beds on the east side. Its position is clearly marked on the shore, where the two divisions of this formation dip towards each other. Part of its course southward is obscured by peat and drift, but about Beinn Dearg Bad Chailleach its position is clear, as a lenticular mass of Cambrian rocks has been let down in the fault. These appear about 170 yds. south of the hill, and include a wedge of Durness Limestone, 3 ft. long and 9 ins. thick in one place, and a much larger mass, probably 30 yds. in length, of a whitish and grey siliceous sandstone or quartzite which is almost certainly a part of the Serpulite Grit. The throw of this fault must be several thousand feet, and it is evidently of post-Cambrian age. For in addition to the evidence already given, it passes through Coigach in its course northwards, and there throws down the Cambrian Quartzite against the local basement beds of the Torridon Sandstone. It appears, however, to be pre-Triassic, and therefore much older in date than the parallel Sand faults. The parallel fault at Second Coast has a downthrow to the east.

Along the shore numerous faults appear both in the Lewisian Gneiss and in the Torridon Sandstone, and give rise to geos or little bays. There is often much crushed material, but probably little displacement of the rocks. These crushes generally trend between N.N.E. and E.N.E. They are numerous in the Torridon area along the north side of Little Loch Broom, and many running in the same general direction give rise to features on the hillside to the south of the loch. Faults having a similar trend are also common in the gneiss region between the two Gruinard Rivers. The north-and-south fault that passes along the Little Gruinard River has a downthrow to the east and is post-Torridon; but the marked crushes or faults in the gneiss which coincide nearly with the course of the Inverianvie River and with that of Uisge Toll a' Mhadaidh are more probably of older date.

The most important of the Loch Broom dislocations is that which for half a mile coincides with the course of Allt a' Bhràighe, the longest of the small streams on the east side of the valley between Inverlael and Braemore. It is a most important feature in the geology of the district, as it repeats the Sgùrr Mòr biotite-schist band and a large part of the underlying rocks. It runs in a general north-east direction, and must have a downthrow to the north-west of about 2000 ft. The mass of fault breccia in places in Allt a' Bhràighe is several yards in width, and the contrast between the biotite-schist on the west or downthrow side and the cliff of flaggy quartz-schist on the east is very striking. This fault has been traced northwards as far as Allt Gleann a' Mhadaidh, where there is also much brecciation, but the displacement cannot be estimated, as rocks of a similar character appear on either side of the crush-line.

On the west side of the valley of Loch Broom there are several important faults between Auchindrean and Garvan which have the same general direction as that of Allt a' Bhràighe. The set which is near to Garvan forms a series of step faults, all throwing down successively to the east, or opposite to the Allt a' Bhràighe dislocation. The largest, which has a downthrow of several hundred feet, is well exhibited in the Garvan Burn, with the course of which it coincides for a long distance. The crush-breccia appears in several places, and the throw is clearly ascertained by the displacements of the lower part of the biotite-schist. Nearer to Auchindrean there is another set of parallel faults, and the rocks are much shattered and disturbed—the general result being downthrows the reverse of those near Garvan. One of the fractures coincides for some distance with the course of Allt Cuil an Droighinn to the west of Auchindrean. Some of these large faults are probably prolonged as far as Loch a' Bhraoin, across the obscure peat-covered ground by Càrn Breac Beag and Loch Badan na Moine, where there seems fair evidence for a large fault with a downthrow to the north-west.

There must also be a large fault along the valley of the River Broom, north of Auchindrean, but it is nowhere exposed.

There is clearly a fault along Allt a' Chumhainn, the burn south of Braemore House. The smashed rock may be observed from the bridge where the main road crosses the stream, and the fault has probably a downthrow on the north side, as the hade is in that direction and the rock overhangs. There appears to be a crush 500 yds. higher up the road, crossing the deep gorge in a N.N.E. direction at the sharp bend in the stream. It is visible in the south bank.

There is another set of faults, with a general direction about east-south-east, of which there are a good many examples about Meall Doire Fàid and to the north of Beinn Enaiglair, where the schists are much contorted. The longest and most important of those near Beinn Enaiglair clearly has a downthrow to the north, as it repeats a portion of the Sgùrr Mòr biotite-schist. All of them give rise to marked features. The fault which passes north of Meall Doire Fàid is probably continuous with that visible in the gorge of the stream to the north-west and with a crush-line which passes up Allt nan Arrachd, the burn west of Beinn Enaiglair. The latter appears in Braemore Wood, where above the footpath the stream runs for about 200 yds. in a narrow gorge only 3 to 4 yds. wide, with perpendicular sides about 100 ft. high. The crush-breccia runs along the burn to the bend at the waterfall, and occurs again in the stream higher up and near the top of the wood.

Much shattered and crushed rock appears for a long distance up Allt Mhucarnaich, above Loch a' Gharbhrain, and the line of crush is prolonged in a south-east direction towards Strathderie in the Sheet (93) to the east, and it probably passes along the course of the Glascarnoch River.

A marked fault accompanied by much brecciation runs in the gorge of Allt a' Chàirn, which forms the northern boundary of the Dundonnell deer forest. It appears to shift the rocks on the north side about 50 yds. to the westward.

A decidedly reddened band to the south of Càrn a' Bhiorain, a hill about 2½ miles west from Inverbroom, has a course nearly north-and-south, and cuts distinctly across the strike of the schist. It can be traced for 200 yds., and in places contains lumps of a metallic ore—probably iron-ore.

CHAPTER XI.

PLEISTOCENE AND RECENT DEPOSITS.

Glaciation and Glacial Deposits.

In the region under description conclusive evidence has been obtained that the topographical features have been profoundly modified during the ice-age. A glance at the map will show that more than half of the area occupied by the Eastern Schists is covered with glacial deposits, and that even among the western mountains most of the valleys are filled with moraines. These deposits not only point to the erosion of the higher plateaux and the transport of materials to lower levels, they also furnish direct proof that the ice moved in different and sometimes in opposite directions during successive stages of the ice-age. Further, it may be observed that, above the limits of the drift, the striæ found on the rocks and the erratic blocks occurring at great elevations furnish supplementary data regarding the history of the period.

The various links in the chain of evidence seem to indicate three periods or distinct phases of glacial conditions:—

1. A period of maximum glaciation when the whole region was apparently enveloped in ice, which for the most part moved westward and north-westward, irrespective of the minor features of the country. In the central part of the region, *the ice-shed, during this stage, was situated at least six miles to the east of the existing watershed at Loch Droma.*

2. A stage when the Fannich Mountains and the mass of high ground between Beinn Dearg and Seana Braigh in the north-east corner of the map were the two great centres of dispersion of glaciers, which became confluent in the valleys and spread over the lower plateaux as a more or less continuous sheet. During this phase the western mountains rose at first as *nunataks* above the ice-field and contributed small glaciers to the confluent ice.

3. A period during which each prominent mass of high ground in this region became an independent ice-centre, and nourished its own glaciers, which followed the natural trend of the valleys. The final stage of glacial conditions is indicated by the terminal moraines in front of the larger corries at high elevations, thus pointing to the existence of corrie glaciers.

The evidence in support of these general conclusions is based on the striæ, boulder-clay, moraines, the distribution of the erratic blocks, and fluvio-glacial gravels. The glacial phenomena produced during the maximum extension of the ice have been largely effaced by the later movements, but the ice-markings and the distribution of the erratic blocks give some striking indications of its extent.

ICE-WORN ROCK SURFACES.

The accompanying map (Fig. 7) is intended to represent the direction of the ice movement during the successive phases of the glaciation of the region, as indicated by the ice-markings. On referring to this map it will be seen that most of the recorded instances occur in the areas occupied by the Lewisian Gneiss, Torridon Sandstone and Cambrian Quartzite to the west of the Moine thrust. The relatively smaller number east of that structural line is due partly to the wider covering of glacial deposits, and partly to the softer character of the Moine Schists. Nevertheless, the rounded form imprinted on the rock surfaces by the grinding action of ice is to be seen in the Fannich Mountains and in the high ground in the north-east corner of the map.

Many of the striæ belong to the period of maximum glaciation when the ice moved independently of the minor physical features. Thus on Sgùrr nan Each, one of the peaks of the Fannich range, at a height of about 3000 ft., the ice-markings point W.N.W. In the south-west part of the same range, on the western part of An Sgùman, at an elevation of 1500 ft., their trend is west, that is across the valley of Allt Coire nam Fear Riabhach. Similar evidence is obtained on the south slope of Beinn Dearg in the north-east part of the map, about 2000 ft. level, where the direction is westerly across the valley of Allt Mhucarnaich.

Again, in the mountainous ground west of the Moine thrust the striæ show that the high plateaux were glaciated by ice moving generally in a W.N.W. or north-west direction, of which the following examples may be adduced. On the plateau of thrust Lewisian Gneiss, north of the Kinlochewe River, round Beinn a Mhùinidh (2231 ft.), the movement was towards the W.N.W., and on the south-west slope of Beinn Làir, above the 1750-ft. level, the markings point in the same direction. It is worthy of note that the volume of ice which passed along the valley of Lochan Fada was thick enough to override the plateau at Loch Garbhaig north-west of Slioch, as indicated by the striæ. Beyond Loch Maree, on the plateau round Meall a' Ghiubhais, and on Beinn a' Chearcaill and A' Chòineach Beag, numerous striated surfaces have been recorded between the 1500-ft. and 1750-ft. contour levels, pointing in a west-north-westerly direction.

North from Loch Maree, on the south slope of Beinn a' Chàisgein Beag, at an elevation of about 1750 ft., the trend of the striæ is north-west, and on the northern declivity of Glas Mheall Mòr, which forms the north-eastern spur of An Teallach, the direction is more northerly.

In many cases the striæ occurring at lower elevations than 1500 ft., especially in the west and north-west parts of the region under description, may have been produced either during the maximum extension of the ice or during the stage of confluent glaciers. These have been expressed in the sketch map (Fig. 7) by feathered arrows. In the lower plateau extending from the Fionn Loch northwards to the Gruinard River, and between the Dundonnell River and Strath Broom, the general trend of the ice-markings varies from W.N.W. to N.N.W.

The striæ further show that during the period of confluent valley glaciers the Fannich Mountains formed one of the main centres of

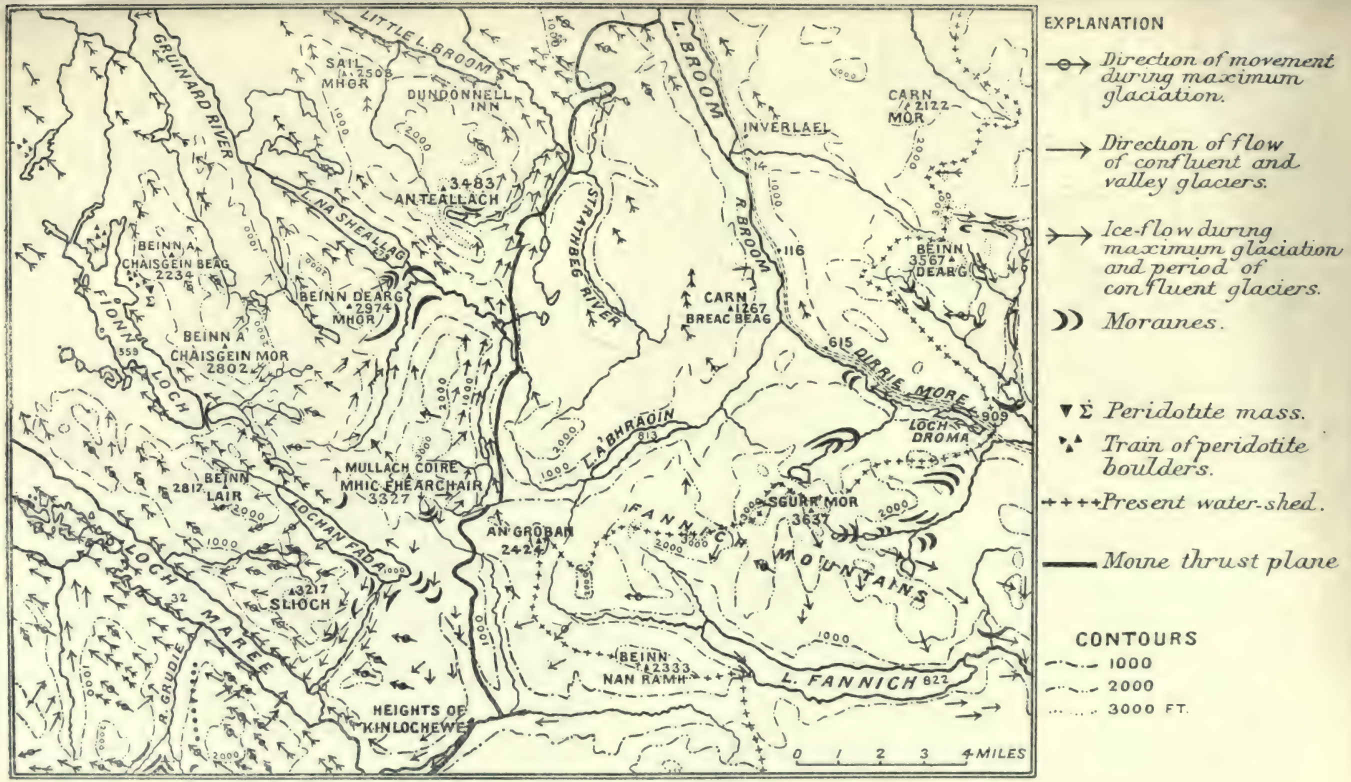


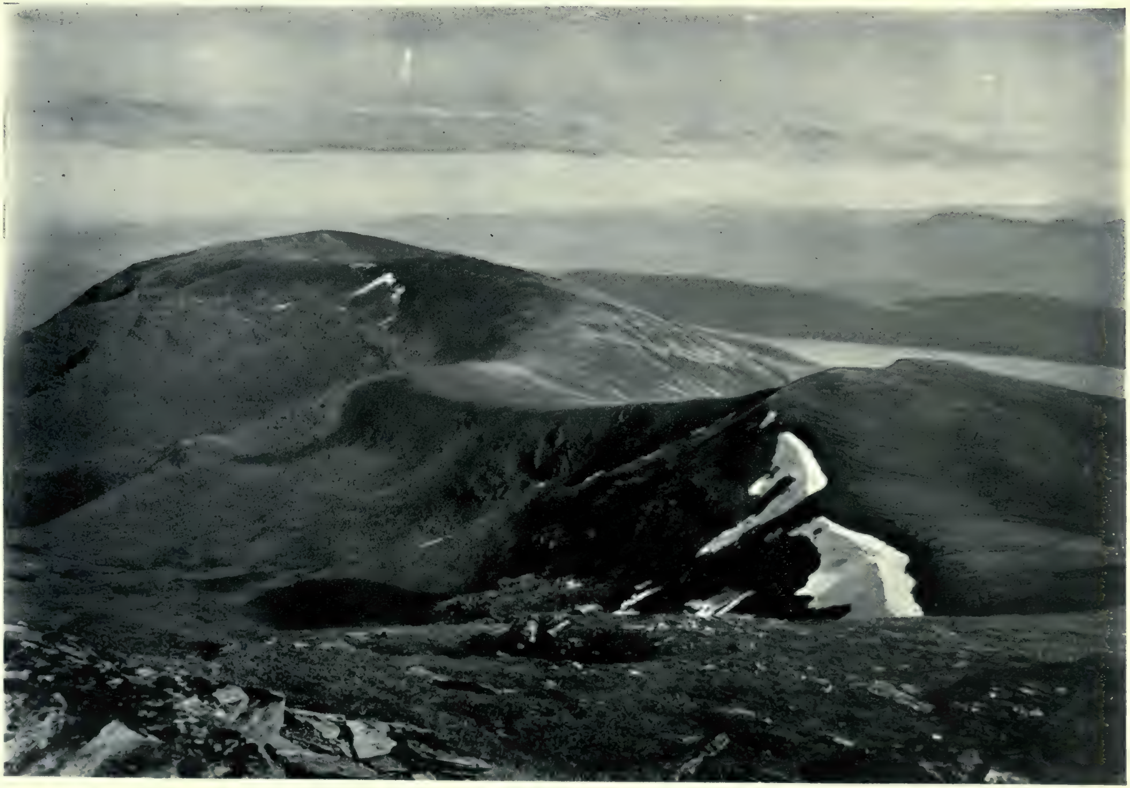
FIG. 7.—Map showing direction of Ice-flow.

dispersion from which the ice radiated in all directions. It passed south-east over the heights at the lower end of Loch Fannich, south across the ridge beyond that loch to Strath Bran (Sheet 82), and north towards Loch Broom. The westerly moving mass was deflected by the great *nunataks* that rose above the ice-field, among which may be mentioned, An Teallach, Beinn a' Chlaidheimh, Sgùrr Bàn, Mullach Coire Mhic Fhearchair, and Slioch. The evidence pointing to this deflection is worthy of note. On referring to the sketch map (Fig. 7) it will be seen that along the hollow extending northwards from Loch an Nid to Dundonnell House the striæ have a northerly trend, while from the south slope of Mullach Coire Mhic Fhearchair down Gleann na Muice to the Heights of Kinlochewe they point towards the south. The volume of ice that moved northwards rose to a high level on the eastern declivity of Sgùrr Bàn and Beinn a' Chlaidheimh. A small part of it streamed over the col separating these peaks, a large portion escaped down the valley of Loch na Sheallag, but a sufficient body was left to find its way northwards over the pass to Dundonnell. Here it was deflected north-westwards towards Little Loch Broom by the ice radiating from the north side of the Fannich range and the high ground in the north-east corner of the map. The ice deflected southwards, escaped down Gleann na Muice and Gleann Bianasdail to the Loch Maree valley, and a part of it advanced north-westwards by Lochan Fada.

The striæ also throw light on the direction of movement of the valley glaciers which radiated from many independent centres throughout the region. They show that when the confluent ice was waning, local glaciers supervened, of which some instances may be adduced. South from Loch Maree there are two important valleys, namely, Srath Lungard and Glen Grudie. Apart from the moraines, the ice-markings prove that they were occupied by glaciers that emanated from the great corries on the north slopes of Beinn Eighe and Beinn Dearg (Sheet 82), and moved north to Loch Maree. Another instance occurs in the valley of Loch Toll an Lochain on the eastern slope of An Teallach (Plate VI.), where the striæ produced by a local glacier point almost due east, that is, nearly at right angles to the direction of movement during the stage of confluent ice. One instance of cross-hatches may be referred to, due to the ice moving in different directions at successive stages. They are to be seen on a boss of Torridon Sandstone in the Dundonnell River, one-third of a mile north-west of Dundonnell Lodge, one set of striæ pointing W. 15° N. and the other nearly due north.

BOULDER CLAY AND MORAINES.

The glacial deposits range from compact bluish boulder-clay or till with striated stones to the loose sandy and gravelly material which forms definite moraines and moraine drift. The former is generally found on smooth, flat, or gently sloping ground, while the latter is usually arranged in conical heaps or ridges. The boulder-clay is often covered with peat, and is rarely met with on the hills or upland glens. It spreads over parts of the lower plateaux and occurs in the lower valleys.



VIEW OF CREST OF EASTERN PART OF FANNICH MOUNTAINS.

Plateau frost-debris arranged in terraces (foreground to right); corries to left in north-east face of chain; Loch Fannich in middle distance.

There is a species of material on some of the hilltops which may be designated plateau frost-débris. It either lies directly above the parent rocks, or has been transported only for short distances.* The materials are frequently arranged in parallel lines or terraces due to soil-creep aided by the movement of snow. This feature is beautifully illustrated in the accompanying photograph of part of the crest of the Fannich range (Plate V.).

The different varieties of drift merge into one another, and it has been found impracticable to separate the till and morainic drift generally over the low grounds, especially as there are few sections in which the glacial deposits are exposed. Both deposits are expressed by one style of ornamentation in Sheet 92.

The glacial drift on the western side of the Broom valley is largely boulder-clay or till, which is specially prominent and of great thickness in the lower part of the Auchlunachan Burn, nearly opposite Inverbroom Lodge, and in the side valley north from Auchindrean farther up the strath. It contains boulders of granitoid gneiss, biotite-gneiss, epidiorite and hornblende-rock which have travelled northwards from the neighbourhood of Loch a' Bhraoin. In the case near Auchindrean, while the lower part of the pre-glacial valley is deeply buried in till, the stream has cut for itself a narrow and deep post-glacial ravine in the flaggy quartz-schists—a fine example of the numerous impassable gorges with waterfalls in which so many of the streams run in this part of Ross-shire.

On the east side of Loch Broom, about a mile north from the head of the loch, there is a great thickness of genuine till with glaciated stones up the Ardcharnich Burn. At the bend in the stream 500 yds. above the road leading to Ullapool a great mass of till with striated stones appears on the north bank. Half a mile higher up is another instance where the thickness of boulder-clay is about 100 ft., as shown on the north side of the northern branch of the burn. A narrow ridge of drift separates this tributary from the main stream on the south, which now runs in a beautiful post-glacial ravine and forms a series of waterfalls about 200 ft. in total height. Near Ardcharnich, marked drift banks, apparently of till and allied to drumlins, run in a north-west direction parallel to that of the general glaciation. There is also a great thickness of boulder-clay in the middle part of Allt Raon a' Chroisg, south-east of Leckmelm. In the highest part of the Broom valley much of the drift is probably genuine till, and in one place there is a section of that deposit about 25 ft. in thickness on the south bank of the river, about a mile up stream from Braemore Lodge.

In the streams east of Kildonan, on the east side of Little Loch Broom, there are several sections in blue boulder-clay with striated stones, many of which are composed of Moine Schist from the eastward, the direction of carry indicated by the adjacent ice-markings on the Torridon Sandstone being north-west.

Much of the drift in the Little Gruinard area in the north-west part of the map is probably boulder-clay. Several exposures by the path at Bad Bog, nearly six miles slightly west of south of Little Gruinard, show a deposit which may be regarded as sandy till.

---

* See "The Geology of Ben Wyvis, Carn Chuinneag, Inchbae and the surrounding country," *Mem. Geol. Surv.*, 1912, p. 159.

Morainic mounds occur not far to the south-east. Again, on the east side of the Fionn Loch, between three-quarters of a mile and two miles north-west of Carnmore, the upper slopes between that loch and the crags are of a smooth character compared with the morainic contour of the drift areas a little farther north and near Eilean Fraoch. In this smooth tract a number of shallow excavations at the side of the forest path disclose a stiff brown sandy clay which frequently shows an obscure lamination inclining south-west, nearly with the slope of the hill. On the south-west side of the Fionn Loch some of the drift is of the same character. The burn about a mile and a quarter south-west of Carnmore old house shows such a deposit lying under looser sandy and gravelly material.

On the north-east side of Loch Maree a stiff brown stony clay is seen in a small burn a quarter of a mile N.N.E. of Letterewe. In another stream about a mile and a quarter north from Letterewe an equally stiff stony clay is exposed beneath a less firmly compacted deposit. Part of the adjoining ground has a smooth, even surface, though a burn section through it shows 30 ft. of drift which is of a loose gravelly character at the top.

On the south-west side of Loch Maree, about a mile and a quarter slightly west of south of Rhu Noa pier, a stream discloses tough grey boulder-clay with many fragments of Moine Schist, which occurs in place about a mile to the south-east.

Reference has already been made to the rare occurrence of boulder-clay in the mountainous regions. It has, however, been observed at considerable elevations in the Fannich range. Thus on the north side of Loch Fannich various pits have been opened at the side of the road between Fannich Lodge and the foot of the loch close by the 800-ft. contour level. Some of these excavations display stiff boulder-clay with striated stones composed of siliceous Moine Schists resembling those in the eastern part of the chain. Others reveal loose moraine matter, which is here sprinkled irregularly over the surface, there being no morainic contour. Again, between 1500 ft. and 1750 ft., the burns draining Coire Beag south of Creachan Rairigidh cut through stiff stony clay overlain by moraines. A still more remarkable instance occurs on the north side of the chain beyond Sgùrr Mòr near the outlet of Loch a' Mhadaidh, which is 1831 ft. above sea-level. Here there is a section of stiff till about 20 ft. thick, with striated stones, while in the corrie to the west of the loch there is the usual morainic contour.

From the evidence now adduced it is clear that throughout the region under description various sections are to be found of stiff boulder-clay with striated stones, indistinguishable in most cases from the usual ground moraine of an ice-sheet. This deposit may have been formed either during the maximum extension of the ice or during the period of confluent glaciers.

The distribution of the moraines shows that they must have been deposited partly during the period of confluent glaciers and partly during the later stage of valley glaciers. They occur throughout the drift-covered areas down to the sea-level. Sometimes they are situated on dividing ridges, sometimes they are spread irregularly over the lower plateaux, but their typical development is to be found in the larger upland valleys.

Taking first the Fannich Mountains, we find that the ice which moved off the southern slopes of that range during the confluent glacier stage crossed the 1500-ft. plateau on either side of Fionn Bheinn (3060 ft.) to Strath Bran. The mounds laid down by the eastern stream are dotted over the moor by Loch na Mòine Mòr and Loch na Mòine Beag, while the western declivity of Fionn Bheinn is terraced with moraines up to the 1750-ft. level, which were deposited by the west branch. All the larger valleys in the Fannich group were occupied by glaciers which left drift heaps behind them. The most extensive assemblage is to be found in the valley of Abhuinn a' Ghiubhais Lì on the north east side of the chain, where they extend for three miles to the east of Loch Lì. Their forms are varied, as, besides the lateral and terminal moraines, there are innumerable small mounds, which, at a distance, give the hillsides quite a mammillated appearance. On the north side of the valley, between half a mile and a mile north-east of Loch Lì, there are straight narrow ridges, some of which extend for 300 yds.

Similar evidence is obtained in the valleys draining the high ground in the north-east corner of the map, where the development of moraines is conspicuous up to high levels. Special allusion ought to be made to the great terminal ridge, upwards of 100 ft. in height, that crosses the valley of Abhuinn a' Gharbhrain like a rampart—a conspicuous object from the Garve and Ullapool road. It effectually blocked for a time the drainage of the valley after the disappearance of the ice, and gave rise to the loch of that name. This valley glacier, which emanated from the corries on the south slope of Beinn Dearg, extended eastwards for several miles along the hollow now occupied by the Glascarnoch River. A fine example of a horseshoe-shaped moraine laid down by a corrie glacier occurs round the outlet of Loch nan Eilean, about a mile and a half south-east from the top of Beinn Dearg.

Passing now to the region lying to the west of the Moine thrust, we find abundant evidence of the occurrence of fragments of Moine Schists in the moraine heaps laid down by the confluent glaciers. They occur in the mounds in Strath na Sheallag, in the valley of Amhainn Loch an Nid, and along Gleann na Muice towards the Kinlochewe River. Blocks of the coarse garnetiferous muscovite-biotite-gneiss have been identified in the morainic drift which must have been transported from the east.

In the area between Little Loch Broom and Strath na Sheallag the size of some of the moraines is remarkable. This tract includes An Teallach, and, as might be expected from the height, mass, and comparative isolation of that mountain, finely-formed, large, local moraines are abundant in its corries. About half a mile south-west of Badbea—a hamlet on the south-west shore of Little Loch Broom—three or four large lateral moraines run north-west, that is nearly parallel with the loch-side. One of them is half a mile long and 40 yds. broad at the base. The trend of these ridges coincides with the direction of the striæ on the Torridonian rocks a little farther south-east. These may, with some probability, be referred to the period of confluent glaciers. In the valley east of Sàil Mhòr that drains the west slope of An Teallach, the morainic drift reaches a depth of 100 ft. in places, and great morainic ridges extend far east towards Mac' us Màthair (2293 ft.), rising gradually to higher ground in that direction. One of them is a mile in length. Its trend varies, but its general strike is slightly north of west. In the valley draining the north-west side of An Teallach, just below Lochan Ruadh, there is an example of a horse-shoe-shaped terminal moraine, and about half a mile north-west of that lochan another moraine crosses the main valley. In the middle corrie on the east side of the mountain, south of Glas Mheall Mòr, a beautifully curved terminal moraine extends across the valley at a height of about 1400 ft. The arc of the curve is nearly half a mile in length in a north-and-south line, and inside the curve are many small mounds, while the outside is free from drift. In the corrie immediately to the south, in which is situated Loch Toll an Lochain, there is a lateral moraine more than a mile long and a terminal moraine also (Plate VI.).

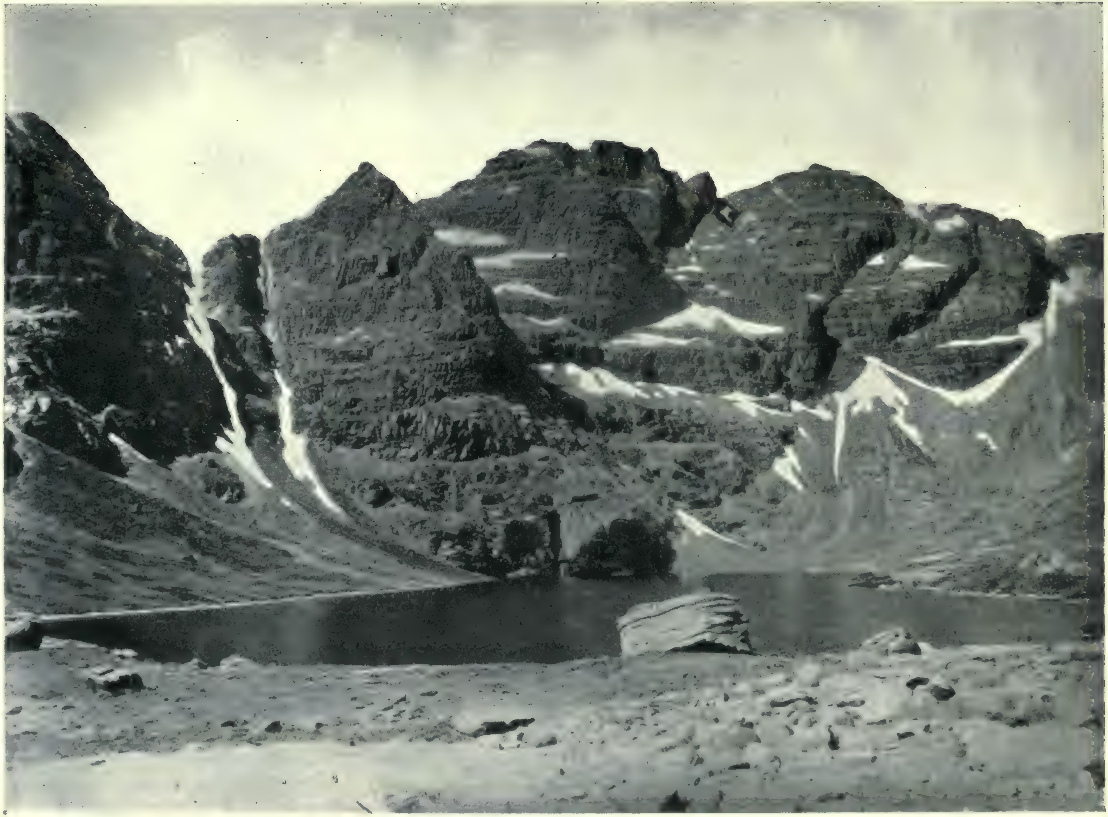
Proceeding southwards to the high ground between Loch na Sheallag and Loch Maree, we find some striking instances of moraines indicating stages in the recession of the valley glaciers, of which a few examples may be adduced. On the north side of Beinn Dearg Mhòr a series of concentric ridges occur near the foot of the stream that drains Loch Toll an Lochain and flows into Loch na Sheallag. The lowest is semicircular and measures nearly half a mile in diameter. In the large corrie on the east side of the mountain still finer examples are to be found. Three successive terminal moraines, laid down by the corrie glacier, form conspicuous features in the landscape. The lowest one, which forms a huge semicircular rampart, stretches for about half a mile across the valley. It measures about 100 or 130 ft. in height on its outer side, and at the lowest point the base is slightly below the 600-ft. contour line.

The glacier that descended Gleann na Muice, south-east of Loch na Sheallag, was one of the largest of the valley system between Loch na Sheallag and Loch Maree. Fed by numerous small tributary ice-streams emanating from the high corries on either side of that valley, it carried downwards towards Strath na Sheallag a large quantity of material derived from the crags and escarpments of Lewisian Gneiss and Torridon Sandstone, which is now distributed in the form of irregular mounds and terraced moraines. In the sequel (p. 106) it will be shown that this glacier interrupted for a time the drainage of Strath na Sheallag and gave rise to fluvio-glacial terraces.

Between Dubh Loch and Fionn Loch, south of Beinn a Chàisgein Mòr, the two arms of a large semicircular moraine come down to the water level about 560 ft. above sea-level. The concave side faces eastwards. A few hundred yards north-east of the highest part of the northern arm, a terrace, composed of sand and gravel and strewn with boulders, can be followed eastwards for half a mile. It rises gently in this direction until it reaches a height of more than 400 ft. above the surface of the Dubh Loch. It seems probable that it was formed by water flowing along the northern side of the same glacier which deposited the semicircular moraine.

In the valley draining the eastern slope of Slioch, between Meall Each and Sgùrr an Tuill Bhàin, a typical horseshoe-shaped moraine

PLATE VI.



Loch Toll an Lochain—A Corrie Rock-Basin in Torridon Sandstone, east side of An Teallach.

occurs about the 1500-ft. contour level, which was laid down by the glacier descending that valley.

South of Loch Maree the moraines in the Grudie valley furnish important evidence of the transport of materials down that depression by the Grudie glacier. In the upper part of the glen, debris of quartzite, derived from the high corries on the north side of Beinn Eighe, forms the chief constituent of the mounds, in marked contrast with the Torridon Sandstone which floors this valley. On the east side the lateral moraines running north-and-south are well defined, and the eye is also arrested by a train of boulders, composed chiefly of quartzite, which has been traced for two miles along the western declivity of Meall a' Ghiubhais between the 1000-ft. and the 1250-ft. contour levels.

ERRATIC BLOCKS.

Two points of extreme interest and importance can be established by the distribution of the erratic blocks in the area under description: (1) that boulders of augen gneiss derived from areas now draining into the North Sea have been transported across the main watershed of the country and carried north-westwards to Loch Broom; (2) that blocks of Moine Schist and thrust Torridon Sandstone have been borne to a height of nearly 3000 ft. on the mountains west of the Moine thrust, where they rest on undisturbed Torridonian and Cambrian strata. It further appears that some of the blocks have ascended about 1500 ft. above their parent source. It seems obvious that in both cases the materials must have been transported during the maximum extension of the ice.*

The evidence supplied by the boulders of augen gneiss is represented in the accompanying sketch map (Fig. 8). It will be seen that the nearest rock masses from which they could have been obtained occur in place in Strathvaich, six miles at least to the east of the existing watershed at Loch Droma. The boulders have been traced across the ridge between Strathvaich and the Glascarnoch River † (Sheet 93) to the neighbourhood of Loch Droma in Sheet 92. On account of the importance of this evidence special notes regarding the size and distribution of these erratics in the catchment basin of Loch Broom were taken by the late Mr. Gunn, details of which may here be given.

A large number occurs N.N.W. of Loch Droma and about half a mile distant from the loch, in two scattered groups, one of which contains 20 and the other 25 blocks. One of the largest measures 7 ft. by 5 ft., and another comprises 120 cubic ft. of rock. Several are perched along the southern slopes of Meall Leacachain, some at a height of 1600 ft. and 1700 ft., and one contains 252 cubic ft. of rock. Others occur in the hollow of Allt Leacachain, about a mile up-stream from the Garve and Ullapool road, between the 1250-ft. and 1500-ft. contour levels. Two of these measure 4 ft. by 3 ft. With the exception of two examples near Braemore Lodge, no other blocks of this type have been detected in Strath Broom till we reach Inverlael. Between that house and Ardcharnich near Leckmelm they are fairly numerous. A group of them is to be found 150 yds. north of Inverlael Lodge, the largest containing about 108 cubic ft. of rock. Several have been noted in the little bay north of Rudha Ard an Tuirc, and also close to the bridge over the stream at Ardcharnich. The largest at the latter locality is 5 ft. long by 4 ft. broad. On the west side of Loch Broom and near the northern margin of Sheet 92, two boulders of this type have been detected about 530 yds. west of north of Dun an Ruigh Ruadh near Blarnalevoch. One of them measures 2 ft. 3 in. in length. The most northerly instance occurs on the shore about 500 yds. north-west of Dun Lagaidh in Sheet 101, within two miles of Ullapool.

---

* With reference to the transport of boulders from the east side of the existing watershed, see "The Ice-shed in the North-West Highlands during the Maximum Glaciation." B. N. Peach and J. Horne, *Rep. Brit. Assoc.*, 1892, p. 720.

† "The Geology of Ben Wyvis, Carn Chuinneag, etc.," *Mem. Geol. Surv.*, 1912, p. 151.

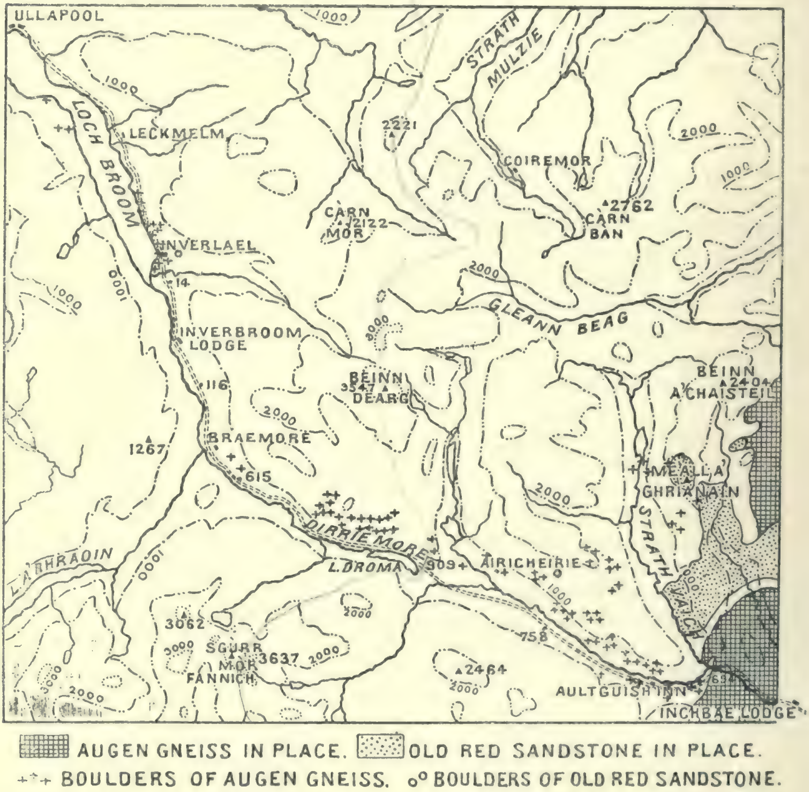


Fig. 8.—Map of parts of Central and West Ross-shire, showing distribution of boulders of Augen Gneiss and Old Red Sandstone.

In connection with the evidence just described, it is worthy of note that a boulder of Old Red Sandstone has been recorded close to Inverlael Lodge (see Fig. 8), which must also have been transported from Strathvaich, as no rock of this type has been found in place in Sheet 92.

Attention will now be directed to the occurrence of erratic blocks at high elevations along the range of mountains stretching from An Teallach to Slioch, in the region situated to the west of the Moine thrust.

On Sàil Liath, which forms the south-eastern spur of An Teallach (3483 ft.), blocks of Moine Schist and thrust Torridon Sandstone have been found close to the 3000-ft. contour level, where they rest upon a small outlier of undisturbed Cambrian Quartzite. In the belt of displaced rocks between Loch Broom and Loch an Nid the thrust Torridon Sandstone does not exceed 1500 ft. in height, hence the erratics of this material must have ascended about 1500 ft. to the ridge of Sàil Liath. Blocks of the Eastern Schists from the interior of the region are fairly numerous all round An Teallach but not over the top. From this evidence the late Mr. Gunn inferred that the highest part of the mountain had never been overridden by the inland ice. He suggested that it might have had a small ice-cap of its own, or that it formed a *nunatak* above the surrounding *mer de glace.*

Farther south, on Sgùrr Bàn (3194 ft.), blocks of thrust Lewisian Gneiss occur about 40 yds. E.S.E. of the cairn and above the 3000-ft. contour line, where they rest on undisturbed Cambrian Quartzite. On Beinn Tarsuinn (2750 ft.) have been recorded erratics of Moine Schist, Lewisian Gneiss, Cambrian Quartzite and Fucoid Beds resting on Torridon Sandstone. On Slioch (3217 ft.), boulders of Moine Schist, thrust Lewisian Gneiss, hornblende-schist and Pipe Rock have been found not far from the cairn on the hilltop with Torridon Sandstone beneath. The blocks of thrust gneiss indicate a minimum uplift of 1000 ft. within a horizontal distance of two and a half miles, while the boulders of Pipe Rock point to a still greater ascent, from any probable parent source along the path of the ice, as indicated by the striæ. Similar evidence is obtained on Sgùrr an Tuill Bhàin (3058 ft.), at a height of about 3000 ft. South from Loch Maree on Meall a' Ghiubhais (2882 ft.) numerous blocks of quartzite, siliceous Moine Schist, and garnetiferous muscovite-biotite-gneiss like the mass on Fionn Bheinn, have been noted between the 2500-ft. contour level and the top of the hill. Scattered over Beinn an Eòin, in some places within a few feet of the hilltop (2801 ft.), there are pieces of Moine Schist, hornblende-schist, and Cambrian Quartzite. The rock *in situ* is Torridon Sandstone.

The facts now adduced regarding the distribution of erratic blocks enable us to furnish an estimate of the thickness of the ice-sheet which transported blocks of Moine Schist to the top of Slioch. The deepest sounding of Loch Maree between that mountain and Meall a' Ghiubhais, ascertained by the Lake Survey, is 367 ft., that is 335 ft. below sea-level. If to this amount we add the height of Slioch above the Ordnance Datum line (3217 ft.), it follows that the thickness of the ice, which crossed this part of the area under description, may have been upwards of 3500 ft., which is greater than the height of An Teallach.

Throughout the area of Lewisian Gneiss in the western part of the map numerous boulders of Cambrian Quartzite and Torridon Sandstone are to be found, which have been carried westwards and northwestwards by the ice during successive stages of the glaciation of the region. The north-westerly movement can be proved independently by the transport of blocks derived from some member of the Lewisian Gneiss itself. Thus from a small outcrop of serpentine and peridotite ¾ ml. E.N.E. of Eilean Fraoch, in the Fionn Loch, a well-defined train of boulders can be traced for a distance of four and a half miles in a north-westerly direction (see Fig. 7).

Again, in the north-west corner of the map to the south of Sand many large boulders of Lewisian Gneiss are scattered over the area of Torridon Sandstone, which have been carried from the Lewisian tract to the south-east.

Some of the erratic blocks are of very large size. For example, a block of biotite-schist in the corrie south-east of Sgùrr Mòr Fannich and 350 yds. north of Loch an Fhuar Thuill Mhòir measures from 10 to 12 yds. in length. Another of the same material is to be found on the boundary between the Braemore and Inverlael deer forests, on the hill named Diollaid a' Mhill Bhric, two miles W.N.W. of Beinn Dearg. It is about 10 yds. long, and a cairn has been erected on the top of it. Again, in the great corrie on the east side of An Teallach, a short distance east of Loch Toll an Lochain, a boulder of Torridon Sandstone contains 5400 cubic ft. of rock.

FLUVIO-GLACIAL SANDS AND GRAVELS.

Reference has already been made to the interruption of the drainage of Strath na Sheallag by the glacier that descended Gleann na Muice. High terraces of fluvio-glacial material extend up that strath for a distance of two miles, from a point about a mile above Loch na Sheallag. The terraces end off abruptly down-stream as if they had been deposited against a barrier that had been removed. On the north side of the strath, a moraine, containing boulders of Lewisian Gneiss that must have emanated from Gleann na Muice, is found on the slope of the hill, which can be traced down the valley for some distance. It crosses the alluvial flat, being there breached by the main stream, ascends the declivity of Beinn Dearg, and eventually passes into Gleann na Muice. This ridge evidently represents the terminal moraine of the Gleann na Muice glacier, which, at its lower end, spread out like a fan when Strath na Sheallag, for some distance above Shenavall, was free from ice. The area occupied by the terraces was probably a temporary lake, perhaps held back by the ice, in which the alluvial detritus from the upper part of the valley was arrested. The terraces cut out of this fluvio-glacial material represent stages in the erosion of the valley by the main stream. The area on the inner side of the terminal moraine opposite Shenavall now forms an alluvial flat, and may represent a silted-up lake impounded by the moraine.

About a mile and a quarter east of Beinn Airidh Charr, two smooth ridges, from 10 to 30 yds. wide at the base, extend in a line south-eastward from a small lochan for a quarter of a mile. They appear to be composed of well-rounded gravel and sand, and may, perhaps, be classed as kames.*

---

* The high-level terraces near Inverbroom and on the north-east side of Loch Maree probably had a different origin from the Raised Beaches (see pp. 109, 110).

FRESHWATER LOCHS.

Of the larger lakes in the area under consideration, some occupy rock-basins and some are due to the irregular distribution of the glacial deposits.

In the case of *Loch Fannich*, the soundings made by the Lake Survey show that it gradually deepens towards the eastern portion, the deepest sounding, 282 ft., being situated about a mile above the outlet. As already indicated, the hill-slopes on both sides of the loch for considerable distances are covered with morainic drift, save on either side of the outlet, where there is a prominent barrier of rock, composed of quartzose granulites and muscovite-biotite-schists. At that point the rocks strike north and south, that is at right angles to the course of the lower part of the lake. At the outlet and for a distance of a mile below it, the Grudie River flows on alluvial deposits, these materials having been largely contributed by side streams, and especially by Allt a' Choin Idhir, draining from the north. Beyond the alluvium at the 800-ft. level, the Moine Schists are exposed on the bed of the river and on the hill-slopes, and there is here no indication of a pre-glacial river channel filled with drift. The surface of Loch Fannich is 822 ft. above Ordnance Datum, so that the depth of the rock-basin below the rocky barrier, visible about a mile beyond the outlet, is 260 ft.

Loch na Sheallag is a simple valley rock-basin, the upper part of which rests on Torridon Sandstone and the lower part on Lewisian Gneiss. Moraines occur on the south-west side for a considerable distance, and they are to be found on the north-east, where the lake narrows. Beyond the outlet the gneiss with its basic dykes descends to the alluvium on either side. The Gruinard River, like the stream issuing from Loch Fannich, flows along an alluvial flat for a distance of nearly a mile and three-quarters below the point where it leaves Loch na Sheallag. Where the alluvium ends there is a small patch of drift on either side of the stream, beyond which, at the level of 263 ft., there is a rocky barrier of Lewisian Gneiss. The deepest part of the lake lies at the upper end, where there is a flat-bottomed basin, 200 ft. in depth, the deepest sounding within that basin being 217 ft. The lake gradually shoals in a north-west direction, till, at the very narrow portion above the outlet, the depth is about fifty feet. As the surface of Loch na Sheallag is 279 ft. above Ordnance Datum, it follows that the depth of the rock-basin is 201 ft. below the rocky barrier exposed in the river below the outlet.

Lochan Fada, north of Slioch, is a simple rock-basin resting partly on Torridon Sandstone and partly on Lewisian Gneiss. Along the greater part of its course it coincides with an old pre-Torridonian valley, trending in a W.N.W. direction. At its eastern end it is bounded by the continuation of the Fasagh fault, which here brings down the Cambrian Quartzites, Fucoid Beds, Serpulite Grit, limestone and the overlying Lewisian Gneiss above the Kinlochewe thrust-plane. The sudden deepening of the loch at its lower end is evidently related to this fault, because harder strata on its east side have been thrown down against the softer Torridon Sandstone to the west. Special attention should be directed to the fact that the downthrow side of this dislocation is towards the east; in other words, the eastern floor of Lochan Fada is not faulted down to the west. It is worthy of note that the deepest part of the basin, and the deepest sounding (248 ft.) lie between Slioch and Beinn Tarsuinn, where the erosion by the ice during the maximum glaciation would probably be greatest.

The Fionn Loch lies wholly within the area of Lewisian Gneiss. It contains several irregular basins, two of them exceeding 100 ft. in depth, and the contour lines in most places are extremely sinuous. The maximum depth of the lake (144 ft.) was recorded in two places, one near the south-eastern end, and the second in the central part of the loch, opposite the mouth of the stream that issues from Lochan Beannach. The eastern arm of the lake east of Aird Dhubh is impounded by drift, which probably fills up a pre-glacial channel. The present outlet is about a mile and a half to the W.S.W. of this locality, and here the Little Gruinard River leaves the loch by a series of rapids and waterfalls. The Fionn Loch is one of the few Scottish lakes which fork downwards.

Loch Maree is a composite rock-basin lying partly along the Glen Docherty shatter belt or fault and partly in Lewisian Gneiss and Torridon Sandstone outside of this line of disturbance. Brief allusion will here be made to the portion of the lake that falls within Sheet 92. This fault runs along the floor of the loch from the mouth of the Kinlochewe River to a point opposite Eilean Subhainn, where it leaves the lake for a short distance, and a little further on skirts the base of the slope behind Ardlair. The soundings of the Lake Survey show that a well-marked U-shaped basin extends from the head of the loch to a point midway between Eilean Subhainn and the north-east shore. The greatest depth, 367 ft., occurs where the valley is most constricted between Slioch (3217 ft.) on the north and Meall a' Ghiubhais (2882 ft.) on the south, and where the erosive action of the ice would naturally be most powerful. Between the small bay one mile W.N.W. from Smiorasair and a point on the shore opposite Coppachy, the effect of a fault in weakening the strata is shown by the widening of the basin and the loop of the 250-ft. contour line in that portion of the lake. To the south and south-west of the islands there is an independent basin, exceeding 200 ft. in depth, evidently resting in Torridonian strata. Loch Maree apparently extended farther up the valley in post-glacial time, but it has been silted up by the streams that converge near Kinlochewe. This part of the lake was probably comparatively shallow, as Eilean na Craoibhe, near the head of the existing loch, is a moraine more or less levelled by the action of the waves.

Loch a' Bhraoin, with a maximum depth of 73 ft., is surrounded by morainic drift, and has been partly determined by a line of fracture.

Loch Garbhaig, to the north of Slioch, is over a mile in length, and evidently a rock-basin from the appearance of Lewisian Gneiss at its exit, where it is drained by the Amhainn na Fùirneis. The soundings prove the existence of two basins separated by a ridge, the eastern one reaching a depth of 93 ft., and the western, 50 ft. close to its outlet. This lake lies mainly along the junction of the Lewisian Gneiss and Torridon Sandstone, the older rocks forming the greater part of the north shore, and the red sandstone the larger portion of the south margin.

Loch a' Bhrisidh, near the 2000-ft. contour line between Sgùrr Bàn and Beinn a' Chlaidheimh, is a typical example of a small rock-basin excavated by ice action at a great elevation. It rests in Torridon Sandstone, the floor being beautifully glaciated at the outlet of the lake. Another example of this type is Fuar Loch Mòr, which occurs above the 1750-ft. level to the north of A' Mhaighdean, where it rests in Lewisian Gneiss.

Loch Droma is impounded by moraines and alluvium, and is partly artificial. It is situated on the main watershed of the North-West Highlands. It has already been shown that in this case the ice-shed during the maximum glaciation must have lain several miles to the east of the present watershed, as proved by the distribution of boulders of augen-gneiss from Strathvaich. Such watersheds have almost invariably had the gradient on each side much lessened, while many have been hollowed into rock-basins.

Among the small lochs on the plateau of Lewisian Gneiss which are bare of drift and may be regarded as true rock-basins, the following may be mentioned:—

Lochan Dubh nam Breac, two miles E.S.E. of Little Gruinard, and two nameless lochans, a third of a mile to the south-east of this one.
A nameless loch three-quarters of a mile S.S.W. of Eilean an Eich Bhàn in the Fionn Loch.
A nameless loch a quarter of a mile north-west of Lochan a' Bhràghad, south of Beinn Dearg Mhòr.
Several lochans, including Lochain Cnapach, three miles S.S.W. of Little Gruinard.

Reference may here be made to the rock-basin, excavated by ice-action, in Little Loch Broom, which has been described by Professor James Geikie.* It extends beyond the limits of the present map into the one-inch Sheet 101. He notes that, at the mouth of the loch, the rock actually comes to the surface at Ardross Rock, north-east of Stattic Point, and that between this islet and the shores the maximum depths are ten and twenty-six fathoms. Yet the soundings half-way up the loch show a depth of fifty-seven fathoms.

B. N. P., J. H., W. G., C. T. C., E. G.

RAISED BEACHES.

The highest beaches of sand and gravel, distinguished in the map by the sign of three inverted crows, are not necessarily of quite the same height in different districts. It is believed, however, that in each the highest parts are not far from 100 ft. above Ordnance Datum.

It should be stated also that there is room for doubt whether some of these platforms are of marine origin. Those on the open coast by Gruinard and Leckmelm may, perhaps, be accepted as marine,† but the high terraces near Inverbroom, four or five miles farther towards the interior, may have a different origin, because in districts a little farther south, as, for instance, in Strath Carron, it is clear that the upper parts of some of the sea-lochs were occupied by ice at the time of the 100-ft. beach.

---

* "The Great Ice Age," 1894, p. 232, *et seq.*

† Leckmelm is only three miles above Ullapool, in one-inch map 101, where the highest raised beach is unusually well developed.

The high terraces on the north-east side of Loch Maree, both those marked with the sign of two inverted crows and one nearly 10 or 12 ft. higher, are not far from the level of 100 ft. If these are marine, it is surprising to find them extending so far into the mountains, and our doubts are increased by the absence of any corresponding terraces on the south-west side of the loch. Possibly these terraces may in reality have been deposited in some sheet of water which was held up between an ice front on the south-west side and the mountains on the north-east.

Most of the terraces indicated by the sign of two inverted crows have their highest parts near the 50-ft. contour, with the exception of those in Loch Maree, as already stated. A good many are seen along the shore near First Coast, Little Gruinard, Kildonan, Dundonnell Inn and Leckmelm. A good section in the terrace near Dundonnell Inn shows gravel at the top with sand and gravel below.

The inner margin of the lowest raised beach is believed to be generally at a height of about 20 ft. Examples of this beach are well seen in Loch Broom and Little Loch Broom.

The tracts between low and high tide marks are of considerable extent at the mouths of the Rivers Gruinard, Inverianvie, Dundonnell and Broom, which is due to the deposition of alluvial material carried down by the streams. Near Little Gruinard the beach mostly consists of sand, but a small portion at the south-west end is composed of gravel and shingle. The northern portion of the beach at the foot of Strath Beg is partly composed of gravel.

FRESHWATER ALLUVIA.

Most of the streams have a steep gradient and considerable carrying power, and, consequently, the terraces formed along their sides are chiefly composed of coarse material, often gravel or even boulder-beds. The older and higher terraces are perhaps best seen near the foot of Strath Beg. The total breadth of the terraces is generally greatest in the lower parts of the valleys, just above the sea or some large freshwater loch. A great part of the flat land at the heads of the lochs has evidently been acquired from the water space during recent times, and it is being continually added to year by year by the material brought down by the streams. A good number of small lochs which once existed have now been entirely filled in this way: as an example of an old loch site we may mention the small alluvial flat at Smiorasair, north-east of Loch Maree. At the head of Loch Maree the flat land is about half a mile wide and extends about two miles up the glen. At the foot of Strath Beg it is less than half a mile wide but about three miles long. Near the foot of the River Broom the total breadth, including some terraces which may be marine, is generally less than half a mile, and the length is about four miles.

When streams descend from steep mountain sides on to much flatter areas, they often deposit great accumulations of gravel and boulders in the form of steep deltas or "cones." Good cones of this description are seen near Carnmore (Fionn Loch), near the head of Lochan Fada, and on the north-east side of Beinn Dearg Mhòr.

PEAT.

In the area west of the Moine thrust the peat has only been mapped in places where it occupies fairly well defined flats or hollows. Some of these areas no doubt represent filled-up lochans, some occupy the bottoms of slacks which have a decided but gentle slope, and others are growths on alluvial terraces. About a mile east of Beinn Airidh Charr, two flats occur, each of which is for the most part covered with peat. The higher moss overlies sand and gravel, and the lower is also probably lying on similar material.

Among the localities where considerable spreads of peat have been noted, though not mapped, the following may be mentioned, all rather near the west margin of the Sheet: west side of Loch a' Mhonaidh-dhroighinn; three-quarters of a mile south-east of Meall na Mèine; by the side of the two large lochs north-west of Lochan Beannach. A great number of smaller patches occur, particularly on the Lewisian Gneiss.

The peat about a third of a mile south-west of the hamlet of First Coast, and in the higher flat a mile east of Beinn Airidh Charr, contains numbers of birch stumps. W. G., C. T. C.

The largest areas of peat are to be found in the tracts lying to the east of the Moine thrust, especially where the Moine Schists are overlain by glacial deposits. Of these, the most extensive one shown on the map is that which covers a great part of the intermediate plateau west from Loch Fannich. The peat is not confined to the plateau, however, for it creeps up the northern and western slopes of Beinn nan Ramh to the crest of that ridge. Westwards it is to be found on the moor between Gleann Tanagaidh and Gleann na Muice.

Although not indicated in the map, this deposit spreads over the greater part of the plateau south of Srath Chrombuill, where it stretches from the top of the slope facing Abhuinn Bruachaig eastwards to the west declivity of Fionn Bheinn. The covering is not continuous, being much interrupted by the streams that dissect the plateau and by long ridges of moraine matter left by the retreating confluent glacier from the Fannich Mountains. Farther east it occupies a large area south from Loch Fannich.

Peat covers the high terrace at the outlet of Loch Fannich, and also the higher alluvial flats of the River Douchary in the north-east corner of the map. The cone of alluvium brought down by the Kinlochewe River to the head of Loch Maree near to Anancaun is partly concealed by peat which extends into Sheet 82 to the south.

B. N. P., J. H.

BLOWN SAND.

Three small patches of blown sand are indicated on the side of the shore north-east and east of Little Gruinard. The two larger rest for the most part on raised beaches.

Besides the above, various patches of blown sand occur far inland, and have evidently been formed from sands deposited in fresh water or from disintegrated Torridon Sandstone. These patches are not shown on the published map. An example of the first-mentioned type occurs at the south-east end of Loch na Sheallag. Those of the second type are especially common in high exposed positions, such as the top of Slioch and the high plateau between An Teallach and Mac' us Màthair. In the latter locality the sand forms dunes comparable to those on the sea-shore. W. G., B. N. P.

CHAPTER XII.

ECONOMIC GEOLOGY.

Iron-Ore.

It is widely known that iron smelting was formerly carried on at various sites on the shores of Loch Maree and the vicinity. From the account given by Mr. J. H. Dixon,* it is clear that a number of prehistoric bloomeries existed in the district, as well as more modern furnaces. The latter were started by Sir George Hay early in the seventeenth century, and were carried on for at least sixty years. Sir George Hay is claimed as the pioneer of the modern iron industry of Scotland, and his furnaces must have been constructed on much more scientific principles than the prehistoric works, for while the slag from the latter yields over 60 p.c. of iron, that from the former yields only 20 or 30.† There is also evidence that some of the ores used in the later furnaces were calcined before being smelted.

One of the historic furnaces was situated at Furnace (whence the name), on the north-east side of Loch Maree, another at Talladale, on the south-west side, and a third, the most recent, called "The Red Smiddy" (one-inch map 91), on the north-east side of the River Ewe, nearly a mile from its mouth.

The presence of the remains and slag heaps of these old furnaces have naturally led people to think that iron-ores of considerable value must exist in the district, but this does not appear to be the case. The only local ores that are known consist of comparatively small pans of bog iron-ore. A good representative of these pans formerly existed at South Erradale (one-inch map 91), where a field wall has been constructed of blocks of iron-ore obtained from it. Some of the blocks are 3 ft. long and 1 ft. thick. Mr. Ivison Macadam made an analysis of two samples of this South Erradale ore with the following results :—

	Ferric Oxide.	Equal to Metallic Iron.	SiO_2.
Sample *a* . .	70·88	49·61	7·48
" *b* . .	66·68	46·67	8·24

Mr. Ivison Macadam adds that the ore was thus equal to many of the red iron-ores and superior to many black-band ores.‡

The pans of bog iron-ore do not appear at present to be either numerous or large. In the map given by Mr. Dixon at the end of his volume none are indicated within the limits of one-inch map 92. But it may be assumed that they were formerly more numerous, and that the best were all used up by the old bloomeries and furnaces. The presence of these local pans may have been one of the inducements which led to the first establishment of the works, but the extensive woods which formerly clothed most of the hillsides were probably a greater attraction, as, from these, fuel and charcoal could be readily prepared for smelting purposes. It is certain that ores not found anywhere in the district were, in later times, imported, for pieces of such ores can still be found lying on the ground near the sites of some of the old furnaces. The only pieces of ore found by Mr. Ivison Macadam near the site of the Fasagh works consisted of bog iron-ore, but near the later works at Furnace red hæmatite and carboniferous clay-ironstone nodules were also used.

---

* "Gairloch," pp. 72–96. Edinburgh, 1886.

† Mr. W. Ivison Macadam, "Notes on the Ancient Iron Industry of Scotland," *Proc. Soc. Antiq. Scot.*, December, 1886.

‡ *Op. cit.*

The rusty scars largely composed of graphitic mica-schist, which extend along the north-east side of Loch Maree from Furnace to Fasagh, are sometimes locally claimed as the source of the ore which was used in the furnaces, and definite spots in these scars have been pointed out as the scenes of former quarrying operations. But the spots may be more reasonably interpreted as the site of small rock slips. These rusty rocks owe their colour to the oxidation of finely disseminated iron pyrites, and it does not seem at all likely that they can ever have been used as iron-ores. Mr. Ivison Macadam estimated that the amount of iron in these rocks, calculated as the metal, varied from a little over 3 to 8 p.c. The few seams, already referred to in Chapter III., which contain magnetite, occasionally yield a considerable proportion of iron, but they are all too thin to be useful sources of supply.*

There is no historical account of the Fasagh furnace, but the level of Lochan Fada appears to have been slightly raised by a dam at the time this furnace was in operation, and water was conveyed in a conduit from this loch to the works, presumably for the purpose of turning water-wheels to work sledge hammers, etc.

LIMESTONE.

The Cambrian limestone which crops out at the south-east end of Lochan Fada has been quarried, and was probably used as a flux in the smelting operations of the adjacent Fasagh furnace.

In addition to the above limestone the Lewisian limestone of Letterewe has also been quarried, under the direction of Mr. Banks, one of the former proprietors of the Letterewe estate, long after the adjoining iron works at Furnace ceased operations. Whether this limestone was also quarried while the iron works were productive is not known. The quarry opened by Mr. Banks was on the west side of the burn about 200 yds. north-west of the ruined house of Folais. It was of considerable size, and was connected with the loch by means of a tramway. The limestone now exposed is about 20 ft. thick, but is a good deal mixed with impurities in the form of biotite and broken lumps of actinolite.

---

* Similar schists, with perhaps in general a somewhat greater amount of magnetite, are found also in one-inch map 91. See "The Geological Structure of the North-West Highlands," *Mem. Geol. Surv.*, 1907, p. 228.

The only other Lewisian limestone which appears to have been quarried in this one-inch map is a band just on the east side of the stream nearly a mile east of Beinn Airidh Charr. The remains of a limekiln are still to be seen in the neighbourhood.

The Liassic limestone in the extreme north-west corner of the map was evidently dug out and burnt in former times, but only to a small extent. One of the old kilns lies about 60 yds. south-west of the shore road, and another lies just outside the map about half a mile farther south. The limestone dug near the first-mentioned locality is of a blue argillaceous character. Near the latter, an old quarry shows 3 or 4 ft. of white but apparently rather sandy limestone. The burnt lime was probably used chiefly for the fields, and at the present time comparatively little lime is used for agricultural purposes.

BUILDING STONE.

The population in the district is very scanty, and there are very few houses or field walls. Of stone suitable for building purposes ample supplies can always be got within reasonable distance. The Torridonian Sandstones and the Moine Schists of siliceous type are of very durable quality, and can be shaped roughly to suitable sizes without much difficulty, but they cannot be easily chiselled down to smooth faces. There are two fairly large quarries in the flaggy quartz-schists of the Loch Broom district, one on the west side of the valley between Auchlunachan and Garvan, and the other, which was opened out by the late Sir John Fowler to supply building stone for Braemore, near the road about half a mile S.S.E. of the house. The beds of Cambrian Quartzite are even more durable. Many of the acid gneisses of the Lewisian Formation are softer and quite suitable for building purposes. The hornblende-schists are generally somewhat harder than these.

ROAD METAL.

The demand for road metal is not great. The length of high road in the map is only about fifty miles, and the forest-paths, so many of which have lately been made in the deer forests, are not broad enough for wheeled vehicles. The material for mending the roads is usually obtained from the immediate vicinity of the portions of road which need repairing. A small excavation is usually made at the side of some mound of morainic drift or in some alluvial terrace. The gravel and sand obtained from the excavation is freed from the larger stones by hand picking and by riddling, and is then wheeled in barrows to the parts of the roads on which it is to be spread. A number of these pits may be seen along the road for about a mile above Braemore Lodge.

METALLIFEROUS VEINS, ETC.

As in the Highlands generally, metalliferous veins appear to be rare and not of a promising character. A fault striking N.N.E. crosses the burn nearly half a mile N.N.W. of Loch Garbhaig, and is accompanied on the east side by a vertical vein, which contains a good deal of galena and copper pyrites, as well as blue and green carbonate of copper. The vein occurs in hornblende-schist, and is at least a foot thick. It cannot be traced beyond the burn, but the fault appears to continue a considerable distance in both directions.

The Lewisian rocks in the burn about three-quarters of a mile N.N.E. of Letterewe House are considerably crushed, and are traversed by a vertical vein of calcite running along the burn in a north-east direction. The vein can be followed about 50 yds., and contains a small quantity of galena as well as iron pyrites.

On the north-east side of Loch Maree, opposite Isle Maree, an excavation or short day-level has been made into the hornblende-schist, perhaps 20 or 30 ft. above the level of the loch. The hole is usually called "Uamh an Oir," which means the "cave of gold." * An inspection of the cave showed that it had been excavated for 7 or 8 yds. along veins of calcite which have a general W.S.W. direction and southerly inclination: no metalliferous ore was noticed excepting a little iron pyrites. Very near the cave various other crushes and calcite veins are observed inclining gently east in the same schist.

The fault that crosses Allt na Faine (a tributary of the Dundonnell River), about a mile and a quarter north-east of the top of Creag Rainich, is accompanied by minor crushes. The joints of the quartz-schist traversed by these lines of movement are, in places, coated with some green mineral, probably a carbonate of copper.

The amount of graphite in the graphitic schists is probably much too small to be of economic value. No specimen of the iron pyrites associated with it in this one-inch map has been analysed, but it is known that the pyrites and pyrrhotite associated with somewhat similar schists in the district of Kintail (one-inch map 72), often contain a trace of gold—too little to repay working.

The pegmatites of Càrn Mòr, on the north-east side of the Fionn Loch, which are described in Chapter III., contain plates of clear white mica of considerable size. Some exceptional examples of these plates attain a length of 9 or 10 ins., and a good many may be as much as 3 or 4 ins. These pegmatites, however, are in a hard, sound condition, and so is the gneiss in which they occur, so that the mica plates would probably be difficult to extract. Moreover, the locality is far removed from any good road, and the minute folds which sometimes affect the plates would impair their value.

PLANTATIONS.

Almost the whole of the land is in a wild, uncultivated condition, and merely used as deer forests for sporting purposes. It is for the most part very bare and treeless, but the islands of Loch Maree and some of the slopes adjoining the loch, particularly on the south-west side, are still clothed with the Scottish fir (*Pinus sylvestris*), the self-sown descendants of older more extensive forests. Within historical times the natural forest growth was much more extensive, and it seems clear that it was partially destroyed in order to provide fuel for the old iron furnaces.

---

* In the "New Statistical Account of Scotland," Edinburgh and London, 1845, p. 93, it is said that the excavation was made by some one who thought he had discovered a silver vein.

Only in one portion of the map, on the Braemore estate at the head of Loch Broom, has planting on a large scale been attempted. As is well known, this experiment has met with a considerable measure of success, and it seems, therefore, probable that a similar system of planting might be carried out with advantage in many other sheltered positions which are now almost treeless. The proximity of the sea would facilitate the transport of timber to more populous centres. The basis of the following particulars about the Braemore plantations has been kindly supplied, through Lady Fowler, by Mr. W. Sinclair, forester, Braemore:—

The late Sir John Fowler acquired Braemore estate in the year 1865, and in that and the two following years he planted close on 5,000,000 trees, at altitudes varying from 100 to 850 ft. above sea-level. Previous to 1865 the timber trees growing on the property consisted almost entirely of self-sown alder and birch, and other indigenous trees common in the Highlands of Scotland. The following measurements of trees, typical of their kind, will, it is believed, convey a fair idea of the rate of growth between the period of planting and the year 1908. The measurement of height is from the ground to the apex of the stem: the circumference is taken at a height of 5 ft. or upwards from the ground.

CONIFEROUS TREES.

Species.	Height.	Circumference.	REMARKS.
	ft.	ft. in.	
Picea excelsa	66	5 0	Grows well.
Pseudotsuga Douglasii	67	7 3	Some are of greater height where in close formation.
Picea Sitchensis (*Menziesii*)	72	6 3	One of this variety, felled recently, was decaying in centre; its circumference was 9 ft.
Pinus sylvestris	60	4 0	Grows well.
Pinus Laricio	55	4 0	Few of this variety; what are, appear healthy.
Pinus austriaca	25	2 6	There were a considerable number of this class planted and found unsuitable; most have been removed; what remains presents a rugged, unhealthy appearance.
Abies pectinata	70	6 5	Grows splendidly here.
Abies nobilis	56	7 5	Grows very well.
Abies lasiocarpa	63	7 0	Only a few of this kind; the measurements given are of the largest.
Abies Pinsapo	37	3 6	More of an ornamental character than commercial.
Thuja gigantea	53	7 0	Grows excellently at low elevations.
Chamæcyparis Lawsoniana	35	5 0	All the cypress varieties thrive well here.
Larix europea	67	4 8	Throughout the plantations thousands of larch are seen 20 ft. higher than this; these measurements are of an average specimen.

HARDWOOD TREES.

Species.	Height.	Circumference.		Remarks.
	ft.	ft.	in.	
Acer Pseudo-platanus	60	3	3	Grows very fast.
Acer platanoides	40	3	0	Grows well.
Æsculus Hippocastanum	38	3	5	Grows well.
Alnus glutinosa	45	5	0	Naturally grown ; here and there disease apparent, due to parasitic fungi.
Betula alba (planted)	56	4	0	The planted birch produces more timber than the natural birch. This is owing to a more regular formation over the ground.
Castanea vesca	53	3	7	Grows well.
Fagus sylvatica	48	5	0	Grows well.
Fraxinus excelsior	58	3	9	Grows very fast in close formation.
Populus (*Canadensis*)	75	5	0	Fast grower.
Tilia (*europœa*)	47	5	8	Grows well.
Quercus pedunculata	50	3	10	This specimen is the best of a number planted the same year.
Ulmus (*montana*)	60	4	0	Grows well.

In the area west of the Moine thrust the peat mosses, though very abundant, are not individually very extensive. Those mosses which are nearest the hamlets and scattered houses are cut for fuel, even though they are but thin and small in extent.

The land under cultivation is mainly confined to the immediate neighbourhood of the hamlets, or to the small gardens and potato plots near isolated foresters' houses. The favourite situations for such plots are the alluvial terraces, which, being composed of light sandy or gravelly soil, can best stand the usually heavy rainfall. The climate, though wet, is in the lower positions usually very mild in winter, the district being so near the west coast. On the other hand, the prevalent wet or cloudy weather in summer leads to a deficiency of summer heat and of ripening power.

RAINFALL.

The following table giving the rainfall in inches for the seven years 1901–7 for three places on the one-inch map being described, and for Kinlochewe, which is in the adjoining map to the south, has been kindly compiled by Mr. Andrew Watt, Secretary of the Scottish Meteorological Society :—

Year.	Braemore House (750 ft. in height).	Loch a' Bhraoin (750 ft. in height).	Loch Droma (850 ft. in height).	Kinlochewe (height ?).
1907	57·65	60·57	58·02	80·67
1906	64·57	66·93	68·60	92·42
1905	65·89	68·50	83·98	82·03
1904	61·83	62·20	80·38	78·28
1903	67·99	...	109·93	103·29
1902	58·20	...	97·46	67·57
1901	56·33	68·52	87·23	...

The heavy rainfall may at some future time help to develop some measure of commercial activity, in the form of water-power schemes. Near and a little east of the Moine thrust the general fall of the ground from east to west is considerable. From the higher ground water might perhaps be carried in conduits along the sides of the glen to the head of Loch Broom, and there precipitated to work turbines on the flat land near the water-side. Loch a' Bhraoin might perhaps be dammed and utilised as a storage reservoir for such a scheme.

Loch Fada, on the north-east side of Loch Maree, is larger than Loch a' Bhraoin, and the fall of the ground, in the distance of about three miles between the former loch and Loch Maree, is nearly 1000 ft. But the gathering ground of Lochan Fada is not very extensive, and the River Ewe, which connects Loch Maree with the sea, is not navigable. W. G., C. T. C.

APPENDIX.

BIBLIOGRAPHY.

LIST OF WORKS REFERRING TO THE GEOLOGY OF THE AREA INCLUDED IN THIS MEMOIR.*

1819. Macculloch, J. "A Description of the Western Islands of Scotland, including The Isle of Man." 3 vols. Lond. Vol. ii. pp. 65, 89–104. "General Remarks on the Sandstone Islands, and on the Sandstone of the Western Coast," vol. iii. pl. xxxii.

1834. Sedgwick, A., and R. I. Murchison. "On the Old Conglomerates, and other Secondary Deposits on the North Coasts of Scotland." *Proc. Geol. Soc.*, vol. i. p. 77.

1835. Sedgwick, A., and R. I. Murchison. "On the Structure and Relations of the Deposits contained between the Primary Rocks and the Oolitic Series in the North of Scotland." *Trans. Geol. Soc.*, Ser. 2, vol. iii. p. 125.

1840. Macculloch, J. "A Geological Map of Scotland." Published by order of the Lords of the Treasury.

1845. "The New Statistical Account of Scotland," by the Ministers of the Respective Parishes, vol. xiv. Inverness, Ross and Cromarty, p. 93.

1852. Sharpe, D. "On the 'Quartz-rock' of Macculloch's Map of Scotland." *Quart. Jour. Geol. Soc.*, vol. viii. p. 120.

1858. Murchison, Sir R. I. "The Quartz-rocks, Crystalline Limestone, and Micaceous Schists of the North-Western Highlands of Scotland, proved to be of Lower Silurian Age, through the Recent Fossil Discoveries of Mr. C. W. Peach, with a Note on the Fossils by J. W. Salter." *Rep. Brit. Assoc.* for 1857, p. 82.

1858. Nicol, J. "Geological Map of Scotland."

1858. Nicol, J. "On the Newer Red Sandstone, and on some other Geological Phenomena, near Loch Greinord, in Ross-shire." *Quart. Jour. Geol. Soc.*, vol. xiv. p. 167.

1858. Murchison, Sir R. I. "On the Succession of Rocks in the Northern Highlands, from the Oldest Gneiss, through Strata of Cambrian and Lower Silurian Age, to the Old Red Sandstone inclusive." *Quart. Jour. Geol. Soc.*, vol. xiv. p. 501.

1859. Murchison, Sir R. I. "Siluria." 3rd ed.

1859. Murchison, Sir R. I. "On the Succession of the Older Rocks in the Northernmost Counties of Scotland, with some Observations on the Orkney and Shetland Islands." [Durness Limestone Fossils described by J. W. Salter.] *Quart. Jour. Geol. Soc.*, vol. xv. p. 353.

1860. Nicol, J. "On the Relations of the Gneiss, Red Sandstone, and Quartzite in the North-West Highlands." *Rep. Brit. Assoc.*, Aberdeen Meeting, 1859, p. 119.

---

* This list has been compiled by Mr. D. Tait.

1861. Murchison, Sir R. I., and [Sir] A. Geikie. "First Sketch of a New Geological Map of Scotland." [Scale 15 miles to an inch.] Edin.

1861. Nicol, J. "On the Structure of the North-Western Highlands, and the Relations of the Gneiss, Red Sandstone, and Quartzite of Sutherland and Ross-shire." *Quart. Jour. Geol. Soc.*, vol. xvii. p. 85.

1861. Murchison, Sir R. I., and [Sir] A. Geikie. "On the Altered Rocks of the Western Islands of Scotland, and the North-Western and Central Highlands." *Quart. Jour. Geol. Soc.*, vol. xvi. p. 171.

1865. Geikie, [Sir] A. "The Scenery of Scotland viewed in Connection with its Physical Geology," 1865. 2nd ed. 1887; 3rd ed. 1901.

1870. Murchison, Sir R. I. "Observations on the Structure of the North-West Highlands." *Trans. Edin. Geol. Soc.*, vol. ii. p. 18; and *Geol. Mag.*, 1870, vol. vii. p. 134.

1876. Geikie, [Sir] A. "Geological Map of Scotland." [Topography by W. & A. K. Johnston. Scale 10 miles to an inch.] Edin. and Lond.

1878. Judd, J. W. "The Secondary Rocks of Scotland." Third Paper. "The Strata of the Western Coast and Islands." *Quart. Jour. Geol. Soc.*, vol. xxxiv. [Gruinard Bay], p. 670.

1878. Hicks, H. "On the Metamorphic and Overlying Rocks in the Neighbourhood of Loch Maree." *Quart. Jour. Geol. Soc.*, vol. xxxiv. p. 811.

1879. Hudleston, W. H. "On the Controversy respecting the Gneiss Rocks of the North-West Highlands." *Proc. Geol. Assoc.*, vol. vi. p. 47.

1880. Bonney, T. G. "Petrological Notes on the Vicinity of the Upper Part of Loch Maree." *Quart. Jour. Geol. Soc.*, vol. xxxvi. p. 93.

1880. Bonney, T. G. "The Pre-Cambrian Rocks of Ross-shire." *Geol. Mag.*, Dec. 2, vol. vii. p. 329.

1880. Hicks, H. "On the Pre-Cambrian Rocks of West and Central Ross-shire." *Geol. Mag.* New ser., Decade ii., vol. vii. pp. 103, 155, 222, 266, 327.

1882. Callaway, C. "The Torridon Sandstone in Relation to the Ordovician Rocks of the Northern Highlands." *Quart. Jour. Geol. Soc.*, vol. xxxviii. p. 114.

1883. Hicks, H. "On the Metamorphic and Overlying Rocks in Parts of Ross and Inverness Shires; with Notes on the Microscopic Structure of some of the Rocks by Prof. T. G. Bonney." *Quart. Jour. Geol. Soc.*, vol. xxxix. p. 141.

1883. Callaway, C. "The Age of the Newer Gneissic Rocks of the Northern Highlands; with Notes on the Lithology by T. G. Bonney." *Quart. Jour. Geol. Soc.*, vol. xxxix. p. 355.

1885. Bonney, T. G. "Anniversary Address of the President," 1885. *Quart. Jour. Geol. Soc.*, vol. xli. p. 50.

1886. Dixon, J. H. "Gairloch in North-West Ross-shire, its Records, Traditions, Inhabitants, and Natural History, with a Guide to Gairloch and Loch Maree." Edin.

1887. Macadam, W. I. "Notes on the Ancient Iron Industry of Scotland." *Proc. Soc. Antiq. Scot.*, vol. xxi. p. 89.

1888. Peach, B. N., J. Horne, W. Gunn, C. T. Clough, L. Hinxman and H. M. Cadell. "Report on the Recent Work of the Geological Survey in the North-West Highlands of Scotland, based on the Field Notes and Maps." *Quart. Jour. Geol. Soc.*, vol. xliv. p. 378.

1888. Teall, J. J. H. "British Petrography; with special Reference to the Igneous Rocks." Lond.

1892. Geikie, [Sir] A. *Annual Report of the Director-General of the Geological Survey* for the year 1891, p. 384. ["Discovery of *Olenellus.*"]

1892. Geikie, [Sir] A. "Discovery of the Olenellus Zone in the North-West Highlands." *Rep. Brit. Assoc.*, Cardiff Meeting, 1891, p. 633.

1892. Peach, B. N., and J. Horne. "The Olenellus Zone in the North-West Highlands of Scotland." *Quart. Jour. Geol. Soc.*, vol. xlviii. p. 227.

1893. Peach, B. N., and J. Horne. "The Ice-Sheet in the North-West Highlands during the Maximum Glaciation." *Rep. Brit. Assoc.*, Edinburgh Meeting, 1892, p. 720.

1894. Geikie, J. "The Great Ice Age and its Relation to the Antiquity of Man." 3rd ed., p. 232.

1894. Peach, B. N. "Additions to the Fauna of the Olenellus Zone of the North-West Highlands." *Quart. Jour. Geol. Soc.*, vol. l. p. 661.

1897. Penck, A. "Geomorphologische Probleme aus Nord-West Schottland." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin.* Band xxxii. pp. 146–191. Abstract in *The Geographical Journal*, vol. xi. (1898) p. 163.

1897. Geikie, Sir A. *Annual Report of the Geological Survey* for the year 1876, pp. 17–18.

1898. Horne, J. "The Recent Discovery in Dundonnell Forest, and its bearing on the Geology of the North-West Highlands." *Trans. Inverness Sci. Soc. and Field Club*, vol. iv. p. 151.

1898. Murray, Sir J., and L. Pullar. "Bathymetrical Survey of the Freshwater Lochs of Scotland." Lond. *Roy. Geogr. Soc.* Lochs of the Broom Basin, p. 37; Gruinard Basin, p. 40.

1898. Goodchild, J. G. "Desert Conditions in Britain." *Trans. Edin. Geol. Soc.*, vol. vii. p. 220.

1898. Mackie, W. "The Felspars Present in Sedimentary Rocks as Indicators of the Conditions of Contemporaneous Climate." *Trans. Edin. Geol. Soc.*, vol. vii. p. 443.

1902. Mackie, W. "Felspars and Climate." *Trans. Inverness Sci. Soc. and Field Club*, vol. v. p. 197.

1902. Horne, J. "Recent Advances in Scottish Geology." [Presidential Address to Section C.] *Rep. Brit. Assoc.*, Glasgow Meeting, 1901, p. 615.

1904. Murray, Sir J., and L. Pullar. "Bathymetrical Survey of the Freshwater Lochs of Scotland." Part VI. "The Lochs of the Ewe Basin." *Geogr. Jour.*, vol. xxiv. p. 546.

1905. Murray, Sir J. "Bathymetrical Survey of the Freshwater Lochs of Scotland." Part VII. "The Lochs of the Conon Basin." *Geogr. Jour.*, vol. xxvi. p. 42. [Loch Fannich.]

1907. Peach, B. N., J. Horne, W. Gunn, C. T. Clough and L. W. Hinxman. "The Geological Structure of the North-West Highlands of Scotland." *Mem. Geol. Surv.*

1910. Geikie, Sir A. "Geological Map of Scotland, reduced chiefly from the Ordnance and Geological Surveys."

INDEX.

Abhuinn a' Chadh' Bhuidhe, 5.
—— a' Gharbhrain, 101.
—— a' Ghiubhais Lì, 4, 101.
—— an Fhasaigh, 5, 16, 18, 21, 26, 33, 44.
—— Bruachaig, 4, 5, 11, 21, 50, 58, 60, 61, 91, 111.
—— Cuileig, 5, 70, 72, 74.
—— Droma, 70, 75.
—— Nid, 77, 78, 79.
—— Srath na Sealga, 4.
A' Chailleach, 67, 68, 69, 70, 78, 79, 80, 81, 82.
A' Chòineach Beag, 96.
Achnashean, 86.
Achneigie, 49, 55.
Acrothele, 50.
Actinolite, 23, 30, 34.
Agriculture, 7.
Allt a' Bhràighe, 70, 71, 72, 92, 93.
—— a' Chàirn, 7, 74, 94.
—— a' Char, 47, 52, 53.
—— a' Chlaiginn, 85.
—— a' Choin Idhir, 84, 107.
—— a' Choire Bhig, 82.
—— a' Choire Mhòir, 80.
—— a' Chumhain, 75, 93.
—— an Eas Bhig, 70, 72.
—— Brebaig, 66, 68.
—— Chnàimhean, 60.
—— Coir' an Leth-Choin, 76.
—— Coire nam Fear Riabhach, 96.
—— Daimh Mòr, 87.
—— Doir' a' Mhuillin, 75.
—— Gleann a' Mhadaidh, 93.
—— Gleann Chaorachain, 47, 55.
—— Leac a' Bhealaich, 67, 77, 79, 87.
—— Leacachain, 75, 103.
—— Loch Ghiubhsachain, 19.
—— Mhucarnaich, 93, 96.
—— na Doire-giubhais, 85.
—— na Faine, 68, 69.
—— na Goibhre, 67, 68.
—— na h-Ighine, 47, 72, 74.
—— na Lairige, 76.
—— nan Arrachd, 93.
—— nan Eilig, 66.
—— Raon a' Chroisg, 74, 99.
—— Righ Iain, 49.
A' Mhaighdean, 2, 39, 42.
Amhainn Loch an Nid, 5, 6, 55, 88, 101.
—— na Fùirneis, 108.
Amphibolite, 26, 87.
—— garnetiferous, 19.
Analyses of Rocks, 21, 29, 33, 35, 36.
Anancaun, 111.
An Cabar, 87.
An Coileachan, 82.
Andalusite, 32.
An Sgùman, 78, 79, 80, 81, 87.
An Teallach, 2, 42, 44, 88, 96, 98, 101, 102, 105, 111.
Applecross Group (Torridonian), 9, 41, 42, 43, 55, 62.
Ardcharnich, 10, 99, 104.
—— Burn, 74.
Ardlair, 91, 108.
Arkoses, 9, 40, 42, 43, 44.
Attadale, 85.
Auchindrean, 93, 99.
Auchlunachan Burn, 99.
Augen-gneiss, 25, 26.
Augite, 35.
Aultbea, 90.
—— Group (Torridonian), 41, 44, 45, 89.
Axinite, 37.

Badbea, 41, 101.
Bad Bog, 99.
Barrow, G., 20, 29.
Beinn a' Chàisgein Beag, 1, 96.
—— a' Chàisgein Mòr, 1, 15, 17, 24, 28, 102.
—— a' Chearcaill, 2, 96.
—— a' Chlaidheimh, 2, 48, 98.
—— Airidh Charr, 2, 15, 16, 31, 35, 37, 106, 111.
—— a' Mhùinidh, 58, 60, 91, 96.
—— an Eòin, 2, 105.
—— Bheag, 58, 82, 91.
—— Dearg, 3, 74, 76, 84, 95, 98, 101, 106.
—— Dearg Bad Chailleach, 45, 89, 92.
—— Dearg Bheag, 2, 3, 15, 19, 20, 23, 25, 27, 42, 83.
—— Dearg Mhòr, 2, 3, 46, 102, 111.
—— Dronaig, 85.
—— Eighe, 98, 103.
—— Enaiglair, 70, 72, 75, 76, 82, 93.
—— Làir, 2, 3, 15, 19, 20, 31, 32, 33, 34, 35, 37, 42.
—— Liath Mhòr a' Ghiubhais Lì, 83.
—— nan Ramh, 87, 111.

Beinn Tarsuinn, 2.
Ben More Thrust, 9, 51, 55, 58.
Biotite-gneiss, 21, 25.
—— -hornblende-schist, 36.
—— schist, 19, 66, 69, 70, 75, 78, 79, 81, 82, 84.
Blarnalevoch, 51, 52, 104.
BONNEY, T. G., 11, 14, 21, 61.
Boulder-clay, 98–103.
Braemore, 5, 10, 71, 72, 73, 75, 92, 93, 103, 117.
Bridge of Grudie, 88.
Broom, River, 4, 5, 109.
Bruachaig, 91.
Building stone, 115.

CABUIE, 87.
—— River, 79, 80, 81, 84.
Cadha Beag, 22, 25, 27.
—— Buidhe, 55.
Camas Mòr, 91.
Cambrian, 46–63.
—— Fucoid Beds, 6, 10.
—— Limestone, 9, 46, 47, 60.
—— Quartzite (*see* also "Pipe Rock"), 2, 9, 10, 46, 47, 53, 60, 62, 63, 89.
Cañons, 5, 6, 74, 99.
Càrn a' Bhiorain, 73, 74, 94.
—— an Lochain, 25.
—— Breac Beag, 72, 93.
—— Breac Mòr, 70.
—— Breac Meadhonach, 72.
—— Daraich, 86.
—— Mòr, 116.
Carnmore, 16, 18, 20, 23, 24, 25, 28, 32, 88, 100, 111.
Càrn na Bèiste, 83, 84.
—— na Crìche, 70.
—— nam Buailtean, 25.
Chlorite schist, 36.
Climate of Torridonian times, 12, 40.
Coigach, 92.
Coire Beag, 100.
—— Riabhach, 83.
Conan, River, 4.
Conglomerate, 9.
Coppachy, 28, 30, 33, 38, 108.
Copper, 116.
Corry Point, 52.
Craig Roy, 60.
Creachan Rairigidh, 82, 100.
Creag an Fhuarain, 67.
—— Bheag, 54.
—— Chorcurach, 47, 53, 54.
—— Dhubh, 70, 72.
—— —— Coil' a' Bhun, 74.
Creag-mheall Beag, 19, 24, 26.
—— —— Meadhonach, 19.
—— Mhòr, 54.
—— na Sgoinne, 19.
—— Rainich, 6, 68, 69, 70.
Cromasag, 63.

DIABAIG GROUP (TORRIDONIAN), 41, 42, 43, 58, 62.
Diollaid a' Mhill Bhric, 76, 106.
Diorite, 24.
DIXON, J. H., 113.
Douchary, River, 5, 111.
Druim Rèidh, 69, 80.
—— Ruadh, 88.
Dubh Loch, 6, 25, 102.
—— —— of Carnmore, 28.
Dun an Ruigh Ruadh, 104.
Dundonnell, 50, 51, 54, 98.
—— Inn, 110.
—— River, 4, 5, 68, 69, 74, 96, 109.
Dun Lagaidh, 104.
Dykes, 9, 15, 18, 19, 21, 24, 25, 26–29, 36, 58, 67, 77, 85, 87, 88.
—— green, 26.

EASTERN SCHISTS, 2, 4, 5, 9, 10, 51, 64–88. (*See* Moine Gneisses.)
—— —— succession in, 65, 66.
Eididh nan Clach Geala, 76.
Eilean Fraoch, 24, 25, 106.
—— na Craoibhe, 108.
—— Subhainn, 91, 108.
Epidosite, 41.
Epidote, 37, 41, 42.
Epidote-biotite-granulite, 73.
Epidote-pyroxene-granulite, 66.
Erradale, South, 113.
Erratic Blocks, 35, 103–106.

FANNICH MOUNTAINS, 3, 10, 64, 95, 96, 99, 100, 101.
Fasagh, 62, 114.
Fault, Fasagh, 14, 39, 44, 48, 58, 60, 61, 91.
—— First Coast, 39, 92.
—— Loch Maree, 14, 39, 44, 48, 61, 91.
Faults, 6, 39, 47, 89, 91–94, 108.
—— pre-Torridonian, 18.
Felsites, 43, 56.
Fionn Bheinn, 11, 85, 86, 87, 111.
—— Loch, 1, 6, 15, 25, 96, 100, 101, 102, 106, 108.
"Findlater Castle Rock," 30.
First Coast, 39, 41, 92, 109, 111.
FLETT, J .S., 88.
"Flinty-crush rocks," 18, 21.
Folais, 16, 17, 18, 20, 34, 35, 113.
Formations, geological, 8.
FOWLER, SIR JOHN, 115, 117.
Frost debris, 99.
Fuar Loch Mòr, 42.
Fucoid Beds, 8, 9, 10, 46, 47, 48, 49, 52, 53, 55, 56, 60, 61.
Furnace, 16, 17, 18, 27, 30, 32, 33, 113, 114.

GALENA, 116.
Garbh Choire Mòr, 82, 84.
Garnet-hornblende-rocks, 87.
Garnets, 37, 68, 69, 71, 78, 84.
Garvan, 70, 93.
GEIKIE, JAMES, 109.
—— SIR A., 12, 34, 43.

Glacial Erosion, 6, 96.
Glaciation, 95–105.
Glackour, 70, 71.
Glascarnoch, River, 5.
Glas Mheall Liath, 48.
—— —— Mòr, 47, 96, 102.
Gleann a' Chadha Dheirg, 76.
—— Bianasdail, 48, 49, 60, 91, 98.
—— na Muice, 5, 58, 98, 101, 102, 106, 111.
—— Tanagaidh, 5, 84, 111.
—— Tùlacha, 3, 4, 16, 17, 18, 30, 32, 38.
—— —— Limestone, 35.
Glen Bruachaig, 11, 27, 50.
—— Docherty, 61, 91.
—— Grudie, 61, 62, 91, 98.
—— Laggan, 14.
—— Logan, 11, 61.
Glenelg, 85.
Goed, 116.
GOODCHILD, J. G., 12.
Graphite, 23, 116.
Graphite-schist, 9, 15, 31, 32.
Gravels, fluvio-glacial, 106.
Groban, 82.
GRUBENMANN, PROF., 20.
Grudie, River, 5, 84.
—— Valley, 103.
Gruinard, 11, 109.
—— Bay, 12.
—— River, 4, 92, 96, 107, 109.

HAY, SIR GEORGE, 113.
HEDDLE, PROF., 14, 61.
HICKS, DR., 11, 15.
Hornblende-chlorite-schist, 34, 36–37.
Hornblende-gneiss, 22, 24.
Hornblende-pyroxenite, 23.
Hornblende-schist, 15, 17, 18, 24, 26, 27, 28, 29, 32, 33, 35–36, 37, 38, 42, 67, 69, 77, 84.
Hornblendite, 23.
Hyolithes, 49, 50.

INISHGLASS, 30, 32, 33, 38.
Inverbroom, 72, 74, 99.
Inverianvie, 6, 23, 25, 92.
Inverlael, 92, 104.
Iorguill, 76.
Iron Ores, 113, 114.

JUDD, J. W., 12, 89, 90.
Jurassic Rocks (*see* Lias), 3.

KAMES, 106.
Kildonan, 99, 109.
Kinlochewe, Heights of, 10, 27, 58, 84.
—— River, 1, 4, 5, 10, 14, 101, 108.
—— Thrust, 9, 10, 50, 51, 56, 58, 60, 61, 62, 98.
Kyanite-gneiss, 16, 32.

LAEL RIVER, 74.
Lamprophyre, 87, 88.
Land surface, pre-Torridonian, 3, 12, 14, 38, 41, 42, 43, 44.
Leckie Burn, 84.
Leckmelm, 10, 99, 104, 109, 110.
Ledgown, 91.
Letterewe, 32, 36.
—— limestone, 16, 25, 34.
—— syncline, 17, 20, 24, 26.
Lewisian Gneiss, 1, 3, 6, 8, 9, 10, 12, 14–38, 49, 52, 55, 56, 58, 62.
—— —— east of Moine Thrust plane, 64, 65, 66, 77, 78, 83, 84, 85, 86.
Lherzolite, 23.
Liassic rocks, 10, 11, 12, 90, 115.
Limestone, 9, 15, 34, 35, 36, 45, 46, 47, 89, 90.
—— quarries, 114, 115.
Linear foliation, 19.
Literature, 11.
Little Gruinard, 22, 23, 28, 39, 41, 111.
—— —— River, 4, 6, 7, 23, 92, 96, 107, 109.
—— Loch Broom, 7, 98, 99, 101, 109.
Loch a' Bhraoin, 5, 6, 68, 69, 70, 91, 108.
—— a' Bhrisidh, 109.
—— a' Chadha Dheirg, 76.
—— a' Chàrnain Bhàin, 47, 52.
—— a' Gharbhrain, 93.
—— a' Mhadaidh, 70, 72, 100.
—— a' Mhadaidh Mòr, 24, 26.
—— a' Mheallain Odhair, 58, 81.
—— a' Mhonaidh-dhroighinn, 111.
—— Allt Eigin, 74.
—— an Daimh, 5.
—— an Dubh nam Breac, 109.
—— an Fhuar Thuill Mhòir, 106.
—— an Nid, 6, 10, 14, 46, 49, 51, 55, 56, 58, 81, 98, 105.
—— an t-Sithein, 70.
—— Badan na Moine, 93.
—— Bad an Sgalaig, 16.
—— Beannachan, 91.
—— Bhanabhaig, 50.
—— Broom, 6, 7, 39, 51, 52, 93, 98, 99, 105.
—— Coire Chaorachain, 55.
—— Droma, 4, 103, 109.
—— Fada, 23, 27.
—— Fannich, 5, 6, 77, 78, 79, 81, 82, 83, 85, 86, 87, 98, 100, 107, 111.
—— Garbhaig, 16, 24, 27, 28, 32, 37, 42, 96, 108.
—— Ghiubsachain, 24, 25.
—— Gruinard, 11.
—— Lagaidh, 46, 47, 52.
—— Lì, 101.
—— Maree, 5, 6, 14, 39, 50, 98, 100, 102, 108, 111, 116.
—— —— Series, 9, 15, 16, 29–38, 111.
—— na h-Uidhe, 16, 19, 20, 25.
—— na Mòine Beag, 101.
—— —— —— Mòr, 85, 86, 87.
—— na Salach, 87.

Loch na Sheallag, 4, 24, 41, 42, 44, 49, 88, 98, 102, 107, 112.
—— nan Eilean, 101.
—— ri Creagain, 73, 74.
—— Toll an Lochain, 67, 69, 87, 88, 98, 102, 106.
Lochain cnapach, 109.
Lochan Beannach, 111.
—— Cnapach, 28.
—— Fada, 3, 5, 6, 18, 30, 32, 35, 37, 46, 58, 73, 91, 98, 104, 111.
—— Feith Mhic'-illean, 25.
—— Fraoich, 73.
—— Gaineamhaich, 25, 41.
—— Giubhais, 25.
—— Iasgair, 27.
—— na Cairill, 23.
—— Ruadh, 102.
Lochs, depths and origin of, 107–109.
"Logan Rock," 61.
Lungard River, 42.

MACADAM, IVISON, 113, 114.
MACCONOCHIE, A., 49, 50.
MACCULLOCH, J., 11.
MACKIE, W., 12.
Mac' us Màthair, 44, 102, 112.
Meall a' Chàirn, 73.
—— a' Chrasgaidh, 68, 69, 87.
—— —— —— Rock, 65, 66, 69, 70, 80, 81, 85, 86.
—— a' Ghiubhais, 9, 10, 14, 40, 43, 48, 50, 51, 62, 91, 96, 103, 105.
Meallan an Laoigh, 56.
—— Chuaich, 80, 81.
—— Ghobhar, 60.
—— Odhar, 86.
Meall an t-Sìthe, 68, 69, 87.
—— —— —— Rock, 65, 66, 68, 69, 78, 79, 85.
—— Doire Fàid, 70, 72, 75, 82, 93.
—— Dubh, 74, 76, 87.
—— Each, 102.
—— Gorm, 82.
—— Leacachain, 103.
—— Mhèinnidh, 2, 31, 35, 37.
—— na Mèine, 111.
—— nan Ceapraichean, 76.
—— Riabhach, 21, 26, 58, 64.
Mica-actinolite-schist, 31.
Mica-pegmatites, 116.
Mica-schist, 9, 15, 30.
Mica-traps, 87, 88.
Moine Gneisses (*see* also Eastern Schists), 3, 6, 53, 54.
—— Thrust, 6, 9, 10, 51, 52, 53, 55, 56, 58, 81, 83, 84, 91.
Moraines, 98–103.
Mullach Coire Mhic Fhearchair, 4, 5, 48, 49, 56, 58, 91, 98.
MURCHISON, SIR RODERICK, 11, 34.
MURRAY, SIR JOHN, 13.
Muscovite-biotite-gneiss, 10, 64. (*See* Meall an t-Sìthe Rock.)
Mylonites, 10, 17, 18, 20, 29, 31, 34, 54, 55, 64, 81.

NEW RED SANDSTONE. *See* TRIAS.
NICOL, J., 11, 89.

Olenellus, 49, 50, 61, 62.
Oykell River, 4.

PEAT, 111, 118.
Pegmatites, 28, 29, 69, 71, 76, 78, 82, 83, 84, 116.
PENCK, A., 12.
Peridotite, 23, 24.
Plantations, 116–118.
Pipe Rock, 46, 47, 48, 54, 55, 60.
Poolewe, 91.
Population, 7.
Pre-Torridonian decomposition, 38.
PULLAR, LAURENCE, 13.
Pyroxene-quartz-rock, 76.
Pyroxenite, 23.

QUARTZ-HORNBLENDE-SCHIST, 19, 32–33.
Quartz-magnetite-schist, 32.
Quartz-schist, 9, 10, 15, 19, 32, 33, 64, 70, 75.
Quartz-tourmaline-rock, 34.
Quartzite, Cambrian. (*See* Cambrian.)

RAINFALL, 118, 119.
Rhidorroch, River, 4, 5.
Rhu Noa, 40, 48, 91, 100.
River Broom, 4, 5, 109.
—— Cabuie, 79, 80, 81, 84.
—— Conan, 4.
—— Douchary, 5, 111.
—— Dundonnell, 4, 5, 68, 69, 74, 96, 109.
—— Glascarnoch, 5.
—— Grudie, 5, 84.
—— Gruinard, 4, 92, 96, 107, 109.
—— Kinlochewe, 4, 5, 14, 101, 108.
—— Lael, 74.
—— Little Gruinard, 4, 6, 7, 23, 92, 108, 109.
—— Lungard, 42.
—— Oykell, 4.
—— Rhidorroch, 4, 5.
—— Systems, history of, 4, 5.
Rock-basins, 6, 107–109.
—— Groups, 8.
Rod structure, 19.
Rudha Ard an Tuirc, 104.
Rudh' Ré, 91.

SÀIL LIATH, 48, 105.
—— Mhòr, 39, 77, 79, 87, 101.
Salterella (*see* Serpulite Grit), 55, 61, 62.
Sand, 12, 90, 92, 106.
—— dunes, 112.
Saussurite, 37.
Scenery, 1–7.

Seana Bhraigh, 3, 76, 95.
Second Coast, 92.
SEDGWICK, PROF., 11.
Serpentine, 24.
Serpulite Grit, 9, 10, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 60, 62.
Sgùrr an Tuill Bhàin, 102, 105.
—— Bàn, 2, 48, 56, 98, 105.
—— Breac, 66, 68, 69, 79.
—— Fiòna, 88.
—— Mòr, 70, 80, 100, 106.
—— —— biotite-schist, 66, 69, 73, 75, 80, 81, 82, 85, 86, 92, 93.
—— nan Clach Geala, 66, 67, 68, 77, 78, 79, 80.
—— nan Each, 77, 78, 79.
Shenavall, 106.
Sillimanite, **33**.
SINCLAIR, W., 117.
Slioch, 2, 3, 15, 33, 42, 44, 98, 102, 105, 112.
Smiorasair, 18, 21, 26, 29, 32, 110.
Srath Chrombuill, 5, 84, 85, 111.
—— Lungard, 3, 15, 44, 98.
Sròn a' Choit, 28.
—— Dubh, 58.
Strathan Buidhe, 16.
Strathanmore, 111.
Strath Beg, 1, 10, 51, 55, 110.
—— Bran, 98.
—— Broom, 1, 103, 104.
Strathderie, 93.
Strath na Sheallag, 10, 46, 55, 101, 102, 106.
Striae, glacial, 96, 97, 98.
Strone Nea, 70.
Syenite, 26, 28.

TAAGAN, 91.
Talladale, 42, 113.
TEALL, J. J. H., 27, 32, 33, 43, 71, 81, 83, 87.
Terraces, fluvio-glacial, 102, 106, 110, 111.
Tinafuline, 12.
Toll an Lochain, 69.
Tomain Coinich, 76.
Tòrr an Fhithich, 33.
Torran Ruadh, 77, 79.
Torridon Sandstone, 2, 3, 9, 10, 12, 38, 39–45, 47, 50, 51, 52, 54, 56, 60, 62, 92.
—— —— basal breccias of, 40.
—— —— subdivisions of, 41.
Tourmaline, 34, 37, 84.
Trias, 3, 10, 11, 89, 92.
Trees, beneath peat, 111.
—— plantations of, 116–118.
Tremolite, 35.
Trilobites, 9, 49, 50.
The Nest, 78, 79, 87.

UISGE TOLL A' MHADAIDH, 92.
Ultrabasic Rocks, 15, 23, 26.
Unconformity, 39, 40, 46, 50, 58, 89.
Uriconian, 43.

VEINS, METALLIFEROUS, 115, 116.

WATER POWER, 119.
Watersheds, 4, 5.
WATT, ANDREW, 119.
Wehrlite, 23.
WILSON, J. S. GRANT, 36.

ZOISITE, 70, 71, 82.
Zoisite-amphibolite, 72, 81, 84.
Zoisite-granulite, 72, 80, 81.

Sco 83
M 92)

LIBRARY
NOV
19
1986
UNIVERSITY OF TORONTO

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

QE
264
G465
1913
c.1
GEOL